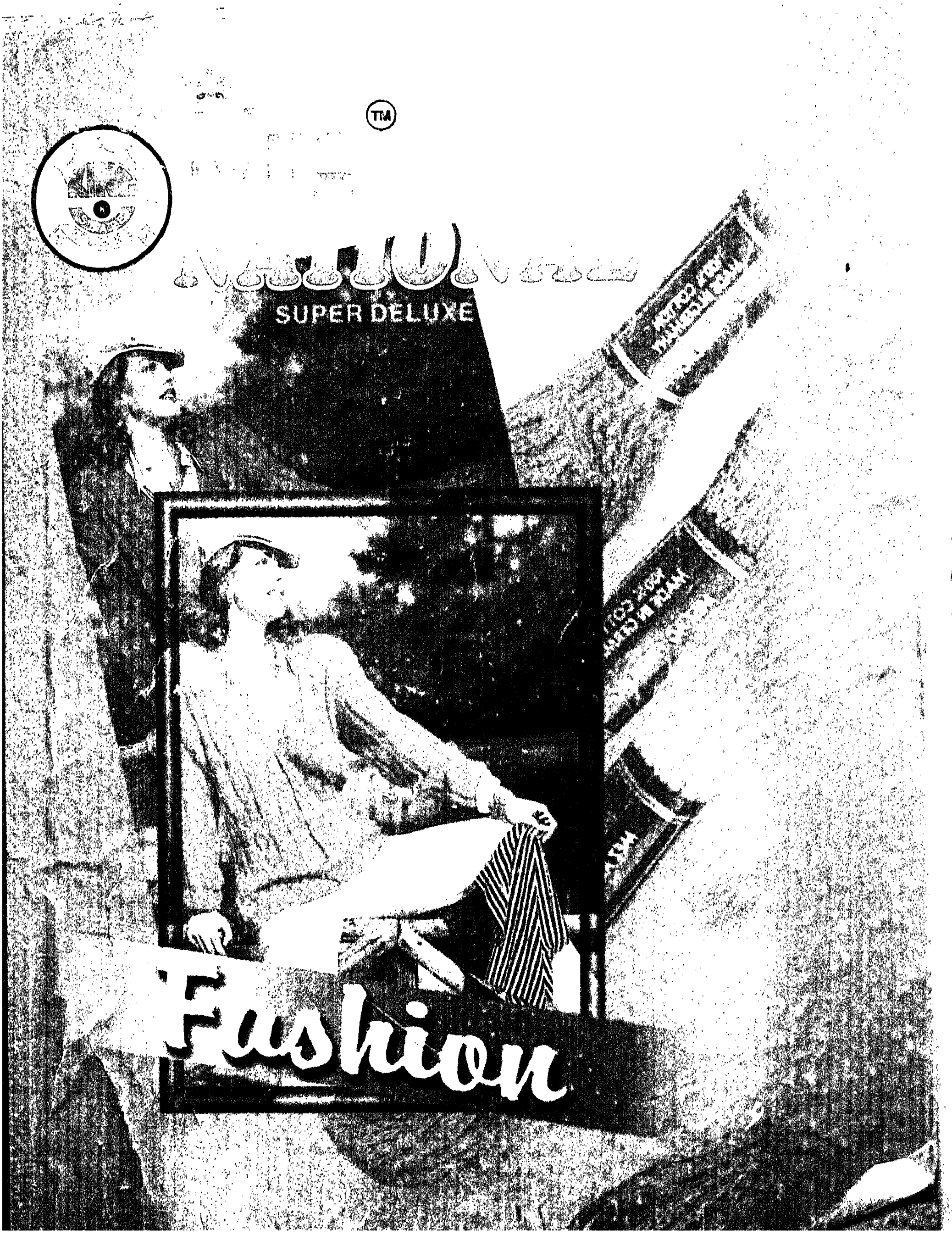
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ENGINEERING ENCYCLOPEDIA

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A Condensed Encyclopedia and Mechanical Dictionary for Engineers, Mechanics, Technical Schools, Industrial Plants, and Public Libraries, Giving the Most Essential Facts about 4500 Important Engineering Subjects

Edited by

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VOLUME I

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Abrasive. An abrasive, such as is used in making grinding wheels or abrasive cloth and paper, may either be natural or artificial. The natural abrasives, such as emery and corundum, have been replaced largely by artificial abrasives, of which there are two general classes. One class is known as silicon carbide abrasives and the other as aluminous abrasives. The raw materials used in making the silicon carbide abrasives are pure glass or silica sand and carbon supplied by coke of various grades. The aluminous abrasives are made from bauxite, which is mined in the southern part of the United States and in various other parts of the world. The two general classes of abrasives mentioned are sold under various trade names. For information about the applications of the silicon carbide and aluminous abrasives see Grinding Wheel Selection. See also Aluminum Oxide and Silicon Carbide.

Abrasive Grading. The modern method of grading abrasives is by the use of screens or sieves having openings between wires of certain standard dimensions. These screens conform to a table in which the wire diameters and the tolerances for both wire diameters and openings are given. Formerly, the number of screen meshes per lineal inch was used to indicate the screen size, but it is evident that accurate screening must take into account possible variations in wire sizes.

The screens used in testing commercial abrasives are made according to specifications of the Bureau of Standards. The openings in successive screen sizes vary by the fourth root of 2, so that every screen is 1.189 times the size of the preceding one. The standard screen or sieve number differs slightly in most cases from the actual number of meshes per inch. For example, a No. 10 screen has 9.2 meshes per inch. A No. 100 screen has 101 meshes per inch, there being slight variations throughout the series with a few exceptions.

The standard screen numbers are applied to loose abrasives used in polishing and also to abrasives used in grinding wheel manufacture. The arbitrary numbers or symbols, such as varying numbers of ciphers, for indicating the grading of certain classes of abrasive paper and cloth have been largely superseded by the standard screen numbers. This standard system of grad-

ing abrasives has been adopted by the Grinding Wheel Manufacturers' Association of United States and Canada.

Abrasive Grit Number. Standard abrasive grain sizes are designated by numbers. These numbers, as approved by the Abrasive Grain Association and Grinding Wheel Manufacturers' Association, range from No. 10 which is the coarsest to No. 220 which is the finest. These numbers, in most cases, equal approximately the number of sieve openings per inch in the United States Standard Sieve Series. For example, a No. 30 sieve has 0.0232-inch openings and a sieve wire diameter of 0.0130 inch, making the pitch equal 0.0362 inch; hence, there are 27.6 meshes per inch. The United States Standard Sieve Series ranges from No. 4 to No. 325.

Grading Abrasives: In the actual grading of abrasives, several standard sieves are used. To illustrate, take grit No. 10. All material must pass through the coarsest sieve—in this case the No. 7. Through the next to the coarsest sieve, termed the "control sieve"—in this case the No. 8—all material may pass, but not more than 15 per cent may be retained on it. At least 45 per cent must pass through No. 8, and be retained on No. 10 sieve, but it is permissible to have 100 per cent pass through No. 8, and remain on No. 10 sieve, the requirement being that the grain passing through No. 8, and retained on No. 10 and No. 12 must add to at least 80 per cent; consequently, if 45 per cent passed through No. 8 sieve and was retained on No. 10 sieve, then at least 35 per cent must be retained on the No. 12 sieve. Not more than 3 per cent is permitted to pass through the No. 14 sieve.

Abrasive-Wheel Cutting Off Process. See Cutting Off Stock with Abrasive Wheels.

Abscissa. In analytical geometry, points are located by designating their distance from two given intersecting lines or axes. In Fig. 1, XX and YY are the axes, generally known as *coordinate* axes. These intersect at point O, called the *origin*. The distances measured parallel to axis XX *ordinates*. In mathematical expressions, the abscissa of a point is generally designated by the letter x and the ordinate by y. The two axes are generally at right angles to each other, in which case they are called *rectangular coordinates*. If the axes are not at right angles to each other, the abscissas and ordinates are measured along lines *parallel* to the axes, and not along lines at right angles to the axes. This is indicated in Fig. 2. The location of the axes is assumed to be known; the location of any point in the same plane, as A, can then be given in terms of its distance from the two axes. For

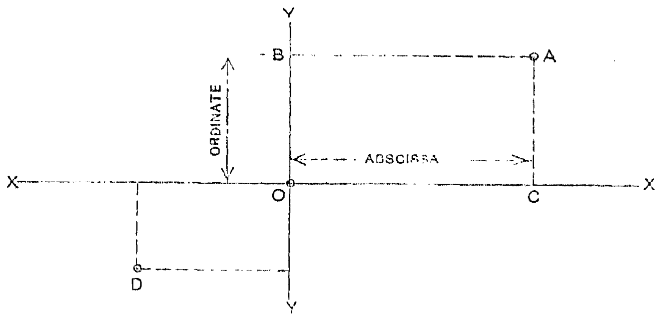


Fig. 1. Rectangular Coordinates

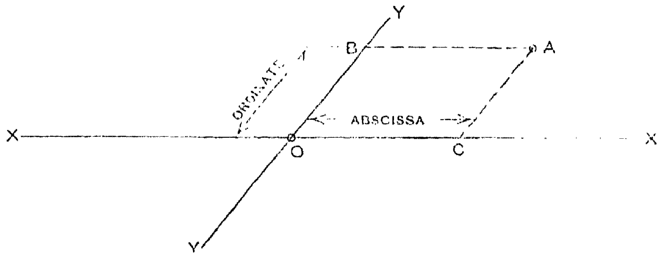


Fig. 2. Measurement of Abscissas and Ordinates

example, if AC equals 2 inches, and AB, 3 inches, the location of point A is definitely given with relation to the axes and the origin.

Abscissas measured to the right of axis YY are *positive* in value, those measured to the left are *negative.* Ordinates measured above the axis XX are positive, those measured below, negative. Hence, both the abscissa and ordinate of point A, Fig. 1, are positive, but of point D, both are negative.

Absolute and Gage Pressure. The pressure of air, gases, or fluids is generally measured either in absolute pressure or in gage pressure. When measured in absolute pressure, the pressure of the atmosphere is included; the gage pressure is the pressure above that of the atmosphere. The pressure of air at sea level is 14.7 pounds per square inch. Gage pressure may be determined by simply subtracting 14.7 from the absolute pressure.

The steam pressure gage of a boiler measures gage pressure. All pressures used in compressed air computations should be measured from an absolute vacuum, which, for ordinary conditions, is 14.7 pounds per square inch below that of atmospheric or *gage* pressure. In like manner, the *absolute temperature* should be used, which for work of this kind may be assumed as equal to the degrees Fahrenheit plus 460.

Absolute Constant. See Constants in Mathematics.

Absolute Efficiency. See Mechanical Efficiency.

Absolute System of Measurement. The system of measurement almost universally used in scientific work is based upon the length and weight units of the metric system, with the second as the time unit. The system is known as the C.G.S. (centimeter-gram-second) system or the "absolute system of measurement." As indicated by the letters C.G.S., the centimeter is the unit of length; the gram, the unit of mass (or weight); and the second, the unit of time. From these basic units are derived a number of other units for measuring velocity, force, work, power, etc. These are:

Unit of velocity = 1 centimeter in one second.

Acceleration due to gravity (at Paris) = 981 centimeters in one second.

Unit of force = 1 dyne = 1/981 gram.

Unit of work = 1 erg = 1 dyne-centimeter.

Unit of power = 1 watt = 10,000,000 ergs per second.

The C.G.S. system of power measurements is used exclusively for electrical machines and apparatus on account of the simple relationship which exists between the various units. The unit of work, erg, is so small that in practical work the *joule* is usually employed instead. One joule equals 10,000,000 ergs.

Absolute Temperature. A point has been determined on the thermometer scale which is called the *absolute zero*, and beyond which a further decrease in temperature is inconceivable. This point is located at —273 degrees Centigrade, or —459.2 degrees Fahrenheit. A temperature reckoned from this point, instead of from the zero on the ordinary thermometers, is called *absolute temperature.* To find the absolute temperature, when the temperature in degrees F. is known, add 459.2 to the number of degrees F. For example, find the absolute temperature of the freezing point of water (32 degrees F.). According to the rule given, 459.2 + 32 = 491.2 absolute temperature Fahrenheit.

Absolute Velocity. The absolute velocity of a moving body, is its velocity with reference to some object which is considered completely at rest. In practical mechanics, the earth is assumed to be stationary, so that the velocity of any moving body, as for example, a moving train with relation to the rails, would be absolute velocity. The term "absolute velocity" is used to distinguish it from *relative velocity,* which is the rate of motion of a body with relation to another moving body. See also Velocity.

Absorptiometer. The absorptiometer is an instrument invented by Prof. Bunsen, with which it is possible to determine

the amount of gas absorbed by a unit volume of a liquid. In its simplest form, this instrument consists of a graduated tube in which a certain quantity of the gas and liquid is agitated over mercury. The amount of gas absorbed by the liquid is measured by the graduations on the scale; the height to which the mercury will rise in pressing up the liquid in the tube, when the gas has been partly absorbed, indicates the degree of absorption.

Absorption Dynamometers. See Dynamometers.

Absorption of Gases. Many liquids have a capacity for taking up or absorbing a certain quantity of gases. The quantity thus absorbed varies with the nature of the liquid and the gas. Many gases, for example, are readily absorbed by water; thus, water will absorb its own volume of carbonic-acid gas, over two times its volume of chlorine, and 430 times its volume of ammonia, but not more than 5 per cent of its volume of oxygen. The weight of gas that a given volume of liquid will absorb is proportionate to the pressure, but as the volume of a given mass of gas is proportionately less as the pressure increases, the volume which a given amount of liquid will absorb at a certain temperature is constant, whatever the pressure. Water, as mentioned, absorbs its own volume of carbonic-acid gas at atmospheric pressure. If the pressure is doubled on both the gas and water, it will still absorb its own volume of the gas under the higher pressure, but, in that case, the density of the gas is doubled and, consequently, double the weight of the gas is dissolved. The quantity of gas absorbed increases as the temperature is lowered. One of the most important instances of the absorption of gases by liquids is met with in the absorption of acetylene by acetone; the latter liquid absorbs, at 60 degrees F. and 180 pounds pressure per square inch, 300 volumes of acetylene gas. This property of acetone makes it possible to safely store and transport acetylene gas in steel cylinders or containers.

Acceleration. The rate of change in the velocity of a moving body is called *acceleration;* hence, the acceleration is the increase in velocity of a body during a very short interval of time, usually one second. When the motion is decreasing instead of increasing, it is called *retarded motion,* and the rate at which the motion is retarded is frequently called the *de-acceleration* or the *deceleration.* The acceleration is said to be uniform if the body gains equal increments of velocity in a given direction in equal successive units of time. A constant force produces a uniform acceleration. Gravity, for example, acting upon a falling body, causes it to fall with a uniformly accelerated motion, providing the effect of the atmospheric resistance is not con-

sidered. The acceleration due to gravity varies from 32.09 at the equator to 32.255 at the poles. The value at sea level and for a latitude of about 41 degrees is 32.16, which is the value commonly used.

Accumulator. An accumulator is a hydraulic machine for the accumulation or storage of energy to be expended intermittently for power purposes, as in riveters, and hydraulic machinery, such as hydraulic elevators and presses. One type consists principally of a vertical cylinder fitted with a plunger, to the upper end of which are secured weights sufficient to produce the required pressure. Water is forced into the cylinder by a pump, raising the plunger and the weights. The plunger and weight react upon the water, when the operating valve at the machine is opened, and cause the pressure to be transmitted to the machinery to be operated. The type of hydraulic accumulator in which the plunger is weighted down is know as the "direct" form. Another type in which the cylinder, fitting over the plunger from above, supports the weights, is known as the "inverted" type. A *storage battery* for electricity may be called an accumulator but the term seldom has this meaning in the United States.

Acetone. Acetone is a liquid obtained by the destructive distillation of acetates and produced, on a large scale, from the watery liquid obtained in the dry distillation of wood. It has the property of absorbing many times its volume of acetylene gas and is, therefore, used to a great extent in the oxy-acetylene welding and metal-cutting industry. The successful use of acetylene gas depends, to a great degree, upon the fact that it can be absorbed by acetone, and thus used without exposing those in the vicinity of the acetylene container to the dangers of a possible explosion from the gas. The method was invented by French engineers in 1896. One volume of acetone at 60 degrees F., under atmospheric pressure, will absorb 25 volumes of acetylene gas. At a pressure of 180 pounds per square inch, 300 volumes of the gas will be absorbed. Hence, by this method, an enormous quantity of acetylene gas can be stored and transported safely under comparatively low pressure, in cylinders of moderate size. When the pressure is relieved, the acetylene gas escapes gradually. The acetone can be used over and over again for the storage of acetylene gas, the loss in acetone being only about one pound for each 1000 cubic feet of acetylene. The porous substance used in the cylinders is a fine fibre or asbestos bound together with silicate of soda, melted in cakes to fill the interior of the cylinders for which they are intended. The material is porous and admits the acetone into the minute cavities.

Acetylene. Acetylene is a gaseous compound of carbon and hydrogen (chemical formula C_2H_2). It is a colorless gas having a specific gravity of 0.92 (air = 1). It is produced by the action of water upon calcium carbide. Acetylene gas cannot be stored in a compressed state directly in cylinders, because of the danger from explosion, but acetylene is soluble in a number of liquids, and, by dissolving in these liquids, acetylene may be stored with safety. Acetone is the liquid generally used for this purpose. Acetylene gas is of the greatest industrial importance in connection with autogenous welding and cutting of metals, where the great heat of combustion, when using it in conjunction with oxygen, is made use of. The oxygen-acetylene flame is far hotter than the oxy-hydrogen flame, and the fact that it is reducing in character is of great advantage in autogenous welding.

Acetylene was discovered in 1836, but until 1892 its production was merely a laboratory experiment. In that year calcium carbide was accidentally manufactured in an electric furnace at the works of the Willson Aluminum Co., in North Carolina. It was considered of no value and was thrown into the river. It was then accidentally discovered that the gas arising from it when thrown into water, would ignite, and a further investigation proved that this was acetylene. Its commercial exploitation began shortly afterward in its use for isolated lighting plants.

Acetylene Generator. A device used for producing acetylene gas, there being two main classes: (1) generators in which water is brought into contact with calcium carbide, the carbide being in excess; and (2) generators in which carbide is dropped into water, the amount of water being in excess.

Acetylene Sludge. The residue or sludge from the carbide in acetylene generators makes a very serviceable whitewash for the workshop, particularly the pits in railroad shops where regular whitewash does not readily adhere to the walls. The sludge from the generating plant may be mixed with water, and is usually spread on the walls by air pressure, the same as ordinary whitewash. It has also been found serviceable as building mortar, and has some value as a fertilizer.

Acheson Process. The method of making silicon carbide—an abrasive used for grinding wheels—by the electric process has, after the inventor, Dr. Acheson, been named the "Acheson process." Silicon-carbide abrasives are produced from quartz and carbon, these substances being heated in an electric resistance furnace. The furnace charge consists of quartz, carbon, sawdust, and sodium chloride. The abrasive is formed at a temperature of 1840 degrees C. (about 3340 degrees F.), and decomposes if it is heated above 2240 degrees C. (about 4060 degrees F.).

Acid. In chemistry, an acid is a compound containing hydrogen in which the hydrogen may be replaced by a metal, or a group of elements equivalent to a metal, to form a salt. An acid is also defined as a compound that will unite with a base to form a salt and water. Most acids are soluble in water, have a sour taste, turn vegetable blue into red, decompose most carbonates displacing the carbonic acid (carbon dioxide) with effervescence; they have also the power of destroying more or less completely the characteristic properties of alkalies. The acids in common use in the industries are hydrochloric, nitric, sulphuric, and hydrofluoric.

Acid Bessemer Process. See Bessemer Process.

Acid Firebrick. A firebrick in which silica predominates and which is generally known as "silica brick."

Acid, Hydrochloric. See Hydrochloric Acid.

Acid, Hydrofluoric. See Hydrofluoric Acid.

Acid Number of Oil. Free fatty acids represent the amount of free organic acid present in the oil, and this should not be confused with mineral acid, as free fatty acids are a normal constituent of the so-called "fixed" or fatty oils. Free fatty acids are determined by titrating in an alcoholic solution with a standard potash solution. The "acid number" is another method of expressing free fatty acids and is the number of milligrams of caustic potash required to neutralize one gram of the fat or oil.

Acid, Picric. See Picric Acid.

Acid-Proof Cement. A cement composed of boiled linseed oil and fireclay resists most acid vapors. A tough and elastic cement is made from 1 part of crude rubber, 4 parts of boiled linseed oil, and 6 parts of fireclay. The rubber is dissolved in carbon disulphide, until a mixture of the consistency of molasses is obtained, and is then mixed with the oil. Asphalt compositions, and compositions of melted sulphur with fillers of stone powder, Portland cement, or sand may also be used as acid-proof cements.

Acid-Proof Tank Lining. A lining for protecting tanks from the corroding effect of acids is made from a mixture consisting of 75 parts (by weight) of pitch; 9 parts of plaster-of-paris; 9 parts of ochre; 15 parts of beeswax; and 3 parts of litharge. The tanks are covered on the inside with a thick coat of this mixture.

Acid-Resisting Alloys. An alloy which has resisted, when subjected to tests, the action of 25 per cent nitric acid for twenty-

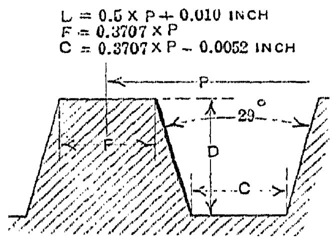
four hours without a measureable loss in weight, consists approximately of 6.5 per cent copper; 1.0 per cent of manganese; 1.0 per cent of silicon; 2.25 per cent of tungsten; 1.1 per cent of aluminum; 0.8 per cent of iron; 4.75 per cent of molybdenum; 21.1 per cent of chromium, and 61.5 per cent of nickel. The melting point of the alloy is approximately 2370 degrees F. When thoroughly liquid, the alloy pours readily and fills the mold perfectly, but the freezing point is so quickly reached that feeding of the casting from risers to make up for shrinkage is practically impossible, while the shrinkage is so excessive that cracks and hollow spots are very difficult to avoid. The material can be machined in a lathe about the same as tool steel. The tensile strength of the cast metal is about 50,000 pounds per square inch. Another acid-resisting alloy which is similar to the preceding one contains: Nickel, 66.6 per cent; chromium, 18 per cent; copper, 8.5 per cent; tungsten, 3.3 per cent; aluminum, 2 per cent; manganese, 1 per cent; titanium, 0.2 per cent; boron, 0.2 per cent; and lithium, 0.2 per cent. This alloy is difficult to cast, but can be forged and drawn into wire. See also Illium.

Acid-Resisting Iron. See Duriron.

Acid Salt. In chemistry, an acid salt is a salt formed when only part of the hydrogen in the acid is replaced by the base.

Acids, Etching. See Etching Acids.

Acme Thread. The Acme thread (see illustration) is extensively used in preference to the square thread, especially for lead-screws and similar parts. The Acme form is stronger than the square thread, and it may be cut with a die more readily than a square thread. When an Acme thread is engaged by a sectional nut like the half-nut of a lathe apron, engagement or disengagement is more readily effected than with a square thread; an adjustable split nut may also be used in connection with an Acme screw thread to compensate for wear and to eliminate back-lash or lost motion. The depth of an Acme thread is made equal to one-half the pitch plus 0.010 inch to provide clearance between the top of the screw thread and the bottom of the thread groove in the nut. The included angle between the sides of the thread is 29 degrees.



Acme Thread

Acmeloy Metal. A group of cast irons with a composition of: Carbon, 2.75 to 3.35 per cent; silicon, 1.00 to 1.75 per cent; manganese, 0.65 to 1.75 per cent; sulphur, less than 0.15 per cent; and phosphorus, less than 0.20 per cent. By varying composition, physical properties can be altered to suit requirements. Tensile strength: As cast, 30,000 to 60,000 pounds per square inch; heat-treated, 75,000 to 85,000 pounds per square inch. Compressive strength: As cast, 125,000 to 175,000 pounds per square inch. Brinell hardness: As cast, 175 to 275; heat-treated, 400 to 600. Cast irons in this group are claimed to be free from hard spots, white edges, and corners, as well as spongy areas, and to be uniformly hard throughout all sections, regardless of the thickness. They are, therefore, especially suitable where machining qualities and dependability as to strength are important factors.

Acronal Resins. Resins that are claimed to be equal to rubber in elasticity. Films of these resins will adhere well to most surfaces. The adhesion is improved by baking or drying. Especially suitable for electrical insulation and for uses where resistance to mineral oils, gasoline, dilute acids, and alkalies is desirable.

Acute Angle. See Angle.

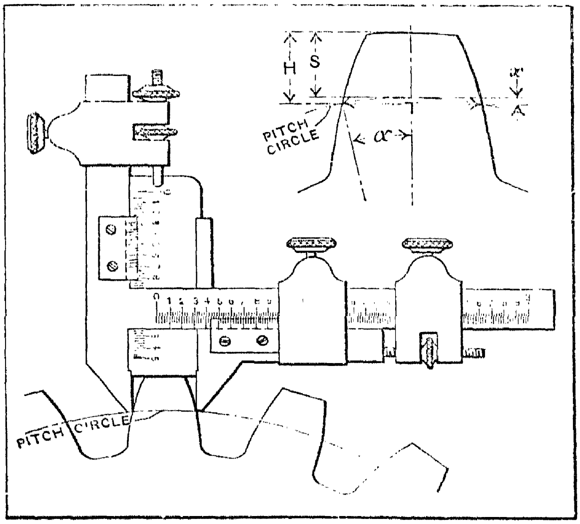
Acyclic Machines. Acyclic machines, sometimes also called *homo-polar* or, incorrectly, *uni-polar*, are direct-current machines in which the voltage generated in the active conductors maintains the same direction with respect to those conductors. Thus, no commutation is required. Their operation is based upon the principle demonstrated by Faraday that when a copper disk is rotated between the poles of a magnet, an electromotive force will be set up between the axis and the periphery of the disk. The machines will operate equally well as motors or generators and have the same inherent features, but are not very extensively used, although attempts have been made to develop this type of generator for high-speed use, as with turbine drives, where commutation is difficult.

Adamantine Boron. A crystalline form of the chemical element *boron.* It has a luster and hardness only slightly inferior to that of the diamond.

Adapter. The term "adapter" is commonly applied to any device for holding a milling cutter or arbor, which, without an adapter, would not fit into the spindle hole or onto the spindle "nose," as the case may be. For example, the standard taper for milling machine spindles is 3½ inches per foot, and the largest diameter of a No. 50 taper is 2¾ inches. If the com-

paratively small shank of an end-mill is to be held in this spindle, an adapter must be used. The outside of this adapter fits into the machine spindle, and a hole in the center has the same taper as the shank of the end mill. This term adapter may also be applied to work-holding or other devices which serve as an intermediate supporting member.

Addendum. The addendum of a gear tooth is the distance (S in illustration) from the pitch circle to the top of the tooth. In standard diametral pitch gearing having full-depth teeth, the addendum is equal to 1 divided by the diametral pitch. The addendum of the American Standard stub teeth, equals 0.8 divided by the diametral pitch. The *corrected addendum* is the perpendicular distance measured from the chord across the tooth at the pitch circle to the top of the tooth, as shown at H in the illustration. This distance is used when measuring the thickness of gear teeth at the pitch line by gear-tooth calipers, as indicated. When a gear tooth is measured in this way, it is the chordal thickness T that is obtained, instead of the thickness along the pitch circle.



Checking Size of Gear Tooth by Measuring Chordal Thickness

If $\alpha =$ one-half of the angle subtended from the center of the gear by one gear tooth (see illustration); $N =$ number of teeth in gear; $T =$ chordal thickness of tooth at pitch line; and $R =$ pitch radius of gear; then:

$$\alpha = 90^\circ \div N; \qquad T = 2R \times \sin \alpha.$$

The height x of the arc equals 1 minus the cosine of angle α, multiplied by the pitch radius of the gear, or, expressed as a formula, $x = R\ (1 - \cos \alpha)$. The vertical scale of the caliper is set to dimension H or $x +$ addendum S.

Adhesion and Friction. Friction should not be confused with "adhesion," which not only resists the motion of one body upon another, but tends to hold the two together so that they cannot be separated. Adhesion is independent of the pressure

between the bodies, while friction increases with the pressure. Moreover, the smoother the rubbing surfaces the greater is the adhesion but the less is the friction; two perfectly smooth surfaces, if such were possible, would be frictionless, while the adhesion between them would be very great, as in the case of precision gage-blocks. Lubricants increase the adhesion and diminish the friction. When the pressure between two bodies is small, the adhesion forms a considerable part of the resistance, and, as the pressure increases, it becomes proportionately less, since adhesion does not increase with the pressure. At ordinary pressures, the effect of adhesion can generally be neglected, and the whole resistance considered as friction. The coefficient of friction of solid rubber tires on cement and vitrified brick roads is about 0.6, while that of pneumatic tires under similar conditions is 0.5. The coefficient of adhesion is greater than that of friction, and incidentally this partly explains why an automobile stops more rapidly when the wheels are kept moving than when they are locked; hence the increased danger when a car skids if the rear wheels are locked by the brakes.

Adhesion, Gage-Block. See Gage-block Adhesion.

Adiabatic Curve. A curve used in a diagram to show the condition under which a gas, such as air, is compressed or expanded in adiabatic compression.

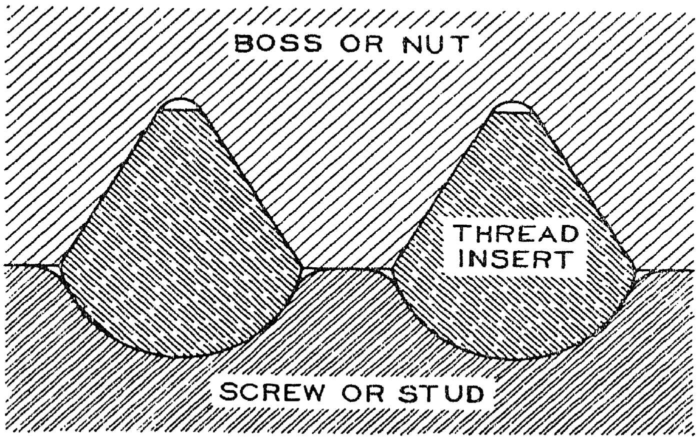
Adiabatic Expansion and Compression. Adiabatic expansion means that heat is neither added nor taken away during the expansion of air or gases; hence such expansion is accompanied by a reduction in temperature. Inversely adiabatic *compression* is accompanied by a rise in temperature. The pressure during adiabatic expansion falls faster than with isothermal expansion and rises faster for adiabatic compression than for isothermal compression. See also Isothermal Expansion and Compression.

Admiralty Metal. A name used for a number of alloys having the property of resisting the action of sea water, and used for parts of engines and machinery on board ships. One alloy consists of 87 per cent of copper, 5 per cent of zinc, and 8 per cent of tin. Another alloy, used for surface condenser tubes exposed to sea water, is composed of 70 per cent of copper, 29 per cent of zinc, and 1 per cent of tin.

Aerometer. Instruments for weighing air or for ascertaining the density of air, gases, or fluids are generally known as *aerometers.* The barometric aerometer is an instrument which consists of a vertical U-tube with open ends, mounted upon a stand in such a manner that it can be used for measuring the

relative specific gravities of liquids. The method in which it is used is as follows: Water is poured into one branch of the tube, and the oil or liquid, the specific gravity of which is to be measured, is poured into the other. The vertical parts of the tube are provided with graduations. If it is found, for example, that 9 inches of water balances 10 inches of oil, then the relative specific gravities are as 10 to 9 or the specific gravity of the oil is 0.9.

Aero-Thread. The name "Aero-thread" has been applied to a patented screw thread system that is especially applicable in cases where the nut or internally threaded part is made from a



The Basic Thread Form Used in the Aero-Thread System

soft material, such as aluminum or magnesium alloy, for the sake of obtaining lightness, as in aircraft construction, and where the screw is made from a high-strength steel to provide strength and good wearing qualities.

The nut or part containing the internal thread has a 60-degree truncated form of thread (See illustration). The screw, or stud, is provided with a semi-circular thread form, as shown. Between the screw and the nut there is an intermediary part known as a thread lining or insert, which is made in the form of a helical spring, so that it can be screwed into the nut. The stud, in turn, is then screwed into the thread formed by the semicircular part of the thread insert.

When the screw is provided with a V-form of thread, like the American Standard, frequent loosening and tightening of the

screw would cause rapid wear of the softer metal from which the nut is made; furthermore, all the threads might not have an even bearing on the mating threads. By using a thread insert which is screwed into the nut permanently, and which is made from a reasonably hard material like phosphor bronze, good wearing qualities are obtained. Also, the bearing or load is evenly distributed over all the threads of the nut since the insert, being in the form of a spring, can adjust itself to bear on all of the thread surfaces.

While it is true that the semicircular thread groove has only about half the shear resistance of the V-thread groove, this is of no consequence when the screw and thread insert are of a high-strength material, as compared with the nut, since the semicircular thread in the insert and the screw will have strength consistent with that of the V-thread in the softer and weaker material from which the nut is made.

Afterblow. That part of the basic Bessemer process during which the phosphorus is oxidized and removed.

Aging. A term used to express the increase in hysteresis loss in the core laminations of electrical machines. See Hysteresis.

Aich Metal. Aich metal is an alloy of about 38 per cent zinc, 60 per cent copper, and 2 per cent iron. Sometimes the iron percentage is only 1.5 per cent. It is malleable at a red heat and can be hammered, rolled, or drawn into fine wire. The metal has been used as a material for cannons. The tensile strength is about 50,000 pounds per square inch; the addition of a small percentage of iron increases the strength perceptibly. At temperatures of from 200 to 1000 degrees F., Aich metal is about 50 per cent stronger than brass of about the same composition, but without the iron. The strength of Aich metal at 200 degrees F. is about 45,000 pounds per square inch; at 500 degrees F., 30,000 pounds per square inch; and at 900 degrees F., 10,000 pounds per square inch. There are a number of alloys of a similar composition, but the principal feature of them all is the addition of iron to a copper-zinc alloy.

Air. Air is a mechanical mixture composed of 78 per cent, by volume, of nitrogen, 21 per cent of oxygen, and 1 per cent of argon. The weight of pure air at 32 degrees F., and an atmospheric pressure of 29.92 inches of mercury or 14.70 pounds per square inch, is 0.08073 pound per cubic foot. The volume of a pound of air at the same temperature and pressure is 12.387 cubic feet. The weight of air, in pounds per cubic foot, at any other temperature or pressure may be determined by first multiplying the barometer reading (atmospheric pressure in inches of

mercury) by 1.325 and then dividing the product by the absolute temperature in degrees F. The absolute zero from which all temperatures must be derived in dealing with the weight and volume of gases, is assumed to be minus 459.2 degrees F. Hence, to obtain the absolute temperature, add to the temperature observed on a regular Fahrenheit thermometer the value 459.2. See also Aerometer.

Air-Balanced Hoist. See under Hoist.

Air Brake Origin. The modern automatic air brake which is employed universally on all railway trains, is the result of the pioneer work done by Mr. George Westinghouse, Jr., who began his experiments in 1869 and was granted his first patents in 1872. These patents have been followed by many others covering features for improving the air brake system. The automatic feature of this air brake system will be apparent when the general operating principle is understood. A continuous pipe line filled with compressed air extends from the locomotive throughout the train length, there being flexible connections between the cars consisting of rubber hose and special couplings. The engineer applies the brake by allowing air from the train line to escape, thus lowering the pressure, which causes valves on the various cars to shift, thus permitting air stored beneath each car to enter the brake cylinders and apply the brakes. If a train should pull apart (an accident liable to happen to a long heavily loaded train), the breaking of the air or train line releases the pressure and all of the brakes are instantly and automatically applied.

Air-Break Switches. See Switches of Air-break Type.

Air Chamber on Pump. Air chambers are used in connection with pump cylinders to reduce shock or "water-hammer," to permit higher speeds, and to give a more uniform discharge of water. The air chamber is attached near the discharge or outlet end. When the discharge occurs, the air in the chamber is compressed by the water, or other liquid, which is forced up into it. The air chamber thus acts as a reservoir and forms a cushion. When the pump plunger is passing the end of its stroke, and the discharge greatly decreases or diminishes entirely, the compressed air in the chamber tends to keep the water moving through the discharge pipe, thus relieving the pump shocks by providing an elastic cushion and equalizing the rate of discharge so that the flow is more uniform.

Air chambers are particularly essential on pumps of the crank-driven type (especially if single-acting), because the speed of the plunger varies decidedly throughout the stroke. Many duplex direct-acting pumps do not have air chambers. The volume of

the air chamber for ordinary boiler-feed and service pumps should be from two to three times the piston displacement for a single-cylinder pump, and from one to two times the displacement for a duplex type. If the piston speed is unusually high, as in the case of fire pumps, the air chamber should have a volume equal to about six times the displacement. Air chambers are sometimes applied to suction pipes, especially if the pipe is long, and the resistance to the flow of water is considerable. The pressure in the suction air chamber is always less than the atmospheric pressure when the pump is in operation, and for that reason it is sometimes called a "vacuum chamber." When the pump is running, the suction air chamber provides a cushion that gradually stops the movement of the column of water at the end of a stroke and assists in starting the water again on the next stroke.

Air Compression. Theoretically, air may be compressed under two different conditions: *Adiabatic* expansion or compression of air takes place when air is expanded or compressed without transmission of heat to or from it, as for example, if air could be expanded or compressed in a cylinder made from a material that was absolutely non-conducting to heat. *Isothermal* expansion or compression of air takes place when air is expanded or compressed with an addition or transmission of sufficient heat to maintain a constant temperature. In actual practice, neither of these two theoretical extremes is obtainable. The work required to compress air isothermally is considerably less than the work required for compressing air adiabatically; the work required for air compression in actual practice is a medium between the work that would be required for either of the two theoretical conditions. See Isothermal Expansion and Compression.

Air Compression, Multi-Stage. For the higher pressures air is compressed in *stages* and cooled between each stage. Single-stage compression is recommended for pressures up to about 50 or 60 pounds (absolute) per square inch; two-stage, for from 50 to 500 pounds; three-stage, for from 500 to 1000 pounds; and four-stage, for higher pressures. The principal reasons for multi-stage compression are: the saving in power by cooling the air as it passes from one cylinder to the next; increased safety with regard to explosion; reduced strain on the compressor; better steam economy in the case of direct-acting steam-driven machines, owing to a better distribution of the load; more effective cylinder lubrication, due to lower air temperatures; greater volumetric efficiency, because the "clearance air" in the first cylinder, being at a lower pressure, does not expand so much on the return stroke, thus allowing an earlier admission of free air to the cylinder; and finally, the delivery of drier air to the receiver,

owing to precipitation during the cooling process between the stages.

Air Compression Terms. The *displacement* of an air compressor is the volume displaced by the net area of the compressor piston. The *capacity* is the actual amount of air compressed and delivered, expressed in free air at intake temperature and at the pressure of dry air at the suction; it should be expressed in cubic feet per minute. *Volumetric efficiency* is the ratio of the capacity to the displacement of the compressor. *Compression efficiency* is the ratio of the work required to compress isothermally all the air delivered by an air compressor to the work actually done within the compressor cylinder, as shown by the indicator cards, and may be expressed as the product of the volumetric efficiency, the intake pressure, and the hyperbolic logarithm of the ratio of compression, all divided by the indicated mean effective pressure within the air cylinder or cylinders. *Mechanical efficiency* is the ratio of the air indicated horsepower to the steam indicated horsepower in the case of a steam-driven machine, and to the brake horsepower in the case of a power-driven machine. *Over-all efficiency* is the product of the compression efficiency and the mechanical efficiency.

Air Compressor. An air compressor may be defined as a machine used for increasing the pressure of air or other gas from a lower to a higher stage by reducing the volume of air or gas or compressing it into a smaller space. Usually, in air-compressor practice, the lower or initial pressure is the atmospheric pressure, while the higher or terminal pressure is fixed by the requirements in each particular case, and may be anywhere from 10 to 30 pounds gage pressure per square inch, in blowing engine practice; from 80 to 100 pounds per square inch for rock drills, pneumatic tools, etc., up to from 1500 to 2000 pounds per square inch, or even higher, for special purposes. Compressors are generally provided with a piston working in a cylinder in which the compression takes place. To a certain extent, the compression of air in the cylinder of a compressor is the reverse of the expansion of steam in the cylinder of an engine. In the case of the former, work is expended upon the air, heat is generated, the pressure increased, and the volume reduced, while with steam, work is done, heat disappears, the pressure is reduced, and the volume increased.

Compressed Air Cooling Methods: Various plans for taking away the heat during compression, such as injecting a spray of water into the cylinder, circulating cooling water through the piston and around the heads and cylinder barrel, etc., have been tried. The use of the cooling spray, or so-called "wet-compres-

sion," has long since been abandoned, as has also the plan of circulating water through the piston, for the disadvantages more than offset the possible gains. Cylinder heads and barrels are water-jacketed, not so much on account of the heat that can be taken from the air as to keep the cylinder cool enough for proper lubrication. The most effective means for taking away the heat of compression and reducing the amount of power required consists, however, in dividing the compression into two or more stages, depending upon the terminal pressure desired, and cooling the air as much as possible between stages by means of suitable cooling apparatus, the water-jacketing of the cylinders and heads being retained for the reason mentioned.

Air Compressor Capacity. The capacity of a compressor is expressed in the cubic feet of *free air* which may be compressed to a given higher pressure in a unit of time. The term "free air" means air at atmospheric pressure, and is commonly taken at 60 degrees F. In designing an air compressor, it is generally required to work out the design for a given volume of air per minute at a given pressure. As compressors are usually rated in cubic feet of free air, it is often necessary to reduce the required volume of compressed air to its equivalent volume of free air. This may be done by dividing the volume of compressed air by the volume of 1 cubic foot of free air at the higher pressure.

Example: A compressor is required to furnish 100 cubic feet of air per minute at a gage pressure of 80 pounds per square inch. What should be its rating in free air?

The volume of 1 cubic foot of free air at 80 pounds gage pressure is 0.267 cubic foot. Therefore, the equivalent free air required by the compressor is:

$$\frac{100}{0.267} = 375 \text{ cubic feet per minute.}$$

Air Compressor Rating. Compressors are often rated upon piston displacement without regard to volumetric efficiency. The actual capacity under working conditions should be considered. The volumetric efficiency is the ratio of the actual volume of air taken into the cylinder per stroke, to the piston displacement, and it varies with the amount of clearance and the terminal pressure. This efficiency is usually 90 per cent or over in compressors of approved design.

Air-Depolarized Cell. An air-depolarized cell is a special type of dry cell designed for constant voltage, closed circuit duty (in contrast with the ordinary dry cell which has a varying voltage and is usually suitable only for intermittent service). Instead of depending upon metallic oxides to supply oxygen for depolarization, this cell is continuously depolarized by air absorption.

Air Engines. There are two types of air engines. In the first type, the force of air expanded by heat in a cylinder causes a plunger to move, a representative engine of this type being the Rider-Ericsson hot-air pumping engine in which gas burners in a furnace below a vertical cylinder heat the air in the bottom of the cylinder, and, through the expansion, cause motion to be transmitted to a pumping piston from which the power may be transmitted. An ingenious mechanism is employed for transferring the air to the upper part of a cylinder where it is cooled off between strokes, and then for transferring it to the bottom of the cylinder to be again expanded. These engines, in sizes of from 5 to 10 inches cylinder diameter, have a capacity for pumping from 150 to 1000 gallons of water per hour to a height of 50 feet.

In another type of air engine, air which has been compressed by a separate air compressor is used as the driving power. This type resembles a steam engine in its general features, having piston, cylinder, and valves of similar construction; the main difference being that compressed air is used as the expanding gas instead of steam. It is used for underground mining machinery, and was formerly applied to overhead traveling cranes, but the electric motor has now taken its place in this and many other applications.

Air-Hardening Steel. The origin of modern high-speed steels may be traced back to a discovery by Robert F. Mushet in 1868. Experiments were being made with the use of manganese in the production of Bessemer steel, and at first there was no idea of improving tool steel. During these experiments it was discovered that one of the bars of steel had the property of hardening after being heated, without quenching or cooling it rapidly in the manner required to harden carbon steel. This steel, which was afterwards known as mushet or self-hardening steel, was found to contain tungsten. The newly discovered steel which possessed the property of hardening when allowed to cool slowly without quenching, proved to be harder than steel which was quenched in the usual way. This discovery of self-hardening or air-hardening steel, as it was also called, led to numerous experiments with different elements in various combinations and, as a result, an alloy steel was obtained which was superior to carbon steel for rapid machining operations. The discovery was made later that the quality of the steel could be improved if the cutting end were reheated and cooled in an air blast, instead of being allowed to cool by simply exposing the heated steel to the atmosphere. An analysis of a typical mushet self-hardening steel showed the following composition: Tungsten, 5.441 per cent; chromium 0.398

per cent; carbon, 2.15 per cent; manganese, 1.578 per cent; silicon, 1.044 per cent.

Airkool Die Steel. A die steel with performance characteristics intermediate between those of high-carbon high-chromium and oil-hardening types. It is air-hardening, wear-resistant, and has non-deforming properties. It is hardened by cooling in air from a temperature between 1750 and 1850 degrees F.; it is tempered to from 63 to 58 Rockwell C. by drawing at temperatures from 300 to 1000 degrees F. Suitable for applications where toughness and wear resistance are the principal requirements.

Air-Lift Pumping. With the air-lift method of pumping, compressed air is supplied to the bottom of a well and mixes with the water. By impregnating with air a column of water in a tube sunk into the water bed, the water is made lighter, so that the pressure of a column of air and water in the bottom of the tube is less per square inch than that of the water outside in the well or in the rock, gravel, or sand strata, so that an upward flow is obtained. The discharge pipe for the water and the pipe for leading the compressed air to the bottom of the well should be properly proportioned. They may be arranged in different ways.

Air, Moisture in Compressed. See Compressed Air, Moisture in.

Air or Vacuum Pump. An air pump or "vacuum pump" is used for exhausting or removing air or other gases from a closed vessel or container, thus producing a partial vacuum. Pumps of this class are extensively used in connection with steam engines and turbine condensers and other condensing apparatus. Air pumps for condenser service may be divided into two general classes known as "wet-air pumps" and "dry-air pumps," according to the conditions under which they operate. Air pumps of the *wet type* handle both air and the water of condensation, and those used with surface and jet condensers are practically the same, except in size, the volume of water handled being much less in the case of the former, as a separate pump is employed for the cooling water. Pumps of the *dry type* have come into use with the advent of the steam turbine, where a high vacuum is required, and are usually of the flywheel or the centrifugal type. They are connected with the condensing chamber in such a manner as to withdraw air only, the condensation being removed by a separate "hot-well" pump. This arrangement makes it possible to use valves designed especially for air, and thus maintain a considerably higher vacuum.

Air Receiver. Air receivers are used in connection with air compressors for the purpose of storing the air, so as to maintain a constant pressure and equalize the pulsations in the air as it comes from the compressor. The receiver also serves the purpose of collecting the water and grease held in suspension by the compressed air, and cools the air before it enters the transmission system. The air receiver plays an important part in obtaining the highest efficiency and most economical operation of a compressed-air installation. It is essential that the cubic capacity of the receiver be in the right proportion to the capacity of the compressor. The receiver should have a capacity of from 15 to 20 per cent of the free air capacity of the compressor (per minute), but, in large installations, the percentage is sometimes lower, and may vary down to about 10 per cent. To obtain good results, the receiver should be placed as near as possible to the compressor, and, in any case, not more than 50 feet distant.

Air Resistance. The resistance of air to the moving parts of machinery often is not considered. Yet still air may offer considerable resistance to parts having a certain form and moving at high speed, as is evidenced by the airplane which is lifted by the action of the propeller and planes against air resistance. Covering large rapidly revolving flywheels on both sides with light plates has a marked effect in reducing the air resistance of the spokes. This is rarely done, however, because of its first cost and appearance. In calculating the power necessary to move a vehicle or projectile, consideration must be given to the resistance of either still air or wind against which it is forced. The wind exerts pressure on sloping roofs and the sides of all buildings, towers, bridges, or any other structure, and they must be able to resist collapsing or overturning because of this force. Even wires have considerable wind resistance, which is increased greatly when they are covered with sleet.

Air Resistance, Racing Car. The amount of power required to overcome air resistance is a factor of importance in the design of racing cars. The horsepower required to overcome the air resistance may be determined approximately by the following rule. Multiply the cube of the velocity of the car in feet per second, by the projected area of the front of the car in square feet, and divide the product by 240,000. The projected area may be approximated by multiplying the width of the car body at the frame-line adjacent to the front seat, by the distance from the center of the wheels to the highest point, which may either be the windshield, the seats, or the top. It will be noted that the foregoing rule merely gives the power required to overcome air resistance and not the actual driving power. In applying this

rule it is assumed that the air is still, but if the car is driven against a wind of known velocity, this velocity should be added to the car velocity. Since air resistance is practically negligible for speeds below 15 miles per hour, it is unimportant in connection with low power cars and ordinary touring speeds.

Air, Saturated. Saturated air is air containing the maximum amount of water vapor possible at any particular temperature and barometric pressure. Atmospheric air usually contains a smaller amount of moisture (water vapor) than saturated air. The amount of moisture in atmospheric air relative to the amount of moisture in saturated air (humidity) is reported daily by the United States Weather Bureau, as well as the mean temperature and the barometric pressure. Variations in the amount of moisture modify the specific heat of air, and therefore the specific heat of dry air at a given temperature should be corrected for the actual humidity condition.

Ajax Metal. Ajax metal is a bearing metal that is composed of 77 per cent of copper, 11.5 per cent of tin, and 11.5 per cent of lead. Another bearing metal, known as *Ajax plastic bronze*, is characterized by a larger percentage of lead, the composition being 65 per cent of copper, 5 per cent of tin, and 30 per cent of lead. This latter metal is considerably cheaper than the Ajax metal itself, because the content of tin, which is the most expensive ingredient, is considerably decreased, and the content of lead, which is the cheapest of the metals used, is increased.

Albion Metal. Albion metal is a combination of tin and lead made by covering lead with sheets of tin. The tin sheets are caused to adhere to the lead by passing the combination between rollers which exert considerable pressure upon the sheets.

Alcohol Anti-Freezing Mixtures. See Anti-freezing Mixtures.

Alden Brake. The Alden brake or absorption dynamometer may be defined as a special form of water-cooled Prony brake. It is capable of absorbing large powers with remarkable steadiness and complete regulation, the characteristic feature being that even for large powers it is moderate in size. The dynamometer consists mainly of a smooth cast-iron disk keyed to a rotating shaft. This disk is enclosed in a cast-iron shell, formed of two disks with a ring at their circumference, which is free to revolve on the shaft. The interior of the cast-iron shell contains two copper disks, fitted to the shell in such a manner that between the sides of the shell and the copper plates there is a water-tight space into which water, under pressure, is admitted, forcing the copper plates against the central disk. The chamber enclosing the central disk is filled with oil. To the outer shell

is fixed an arm with weights, which resists the tendency of the shell to rotate with the shaft, this tendency being caused by the friction of the copper plates against the central disk.

Algebra. That part of mathematics known as *algebra* may be defined as a generalized arithmetic. In arithmetic, the answer to a specific problem is always required. In algebra, a general solution is usually desired, which may be applied to all problems of a similar character. A quantity in mathematics is any number involved in a mathematical process, and, in algebra, letters are used instead of figures to represent numbers or quantities. The use of letters or symbols in place of the actual numbers simplifies the solution of mathematical problems and makes it possible to obtain the result more rapidly and accurately. The symbols used in algebra are mainly the letters of the alphabet. Ordinarily, the first letters of the alphabet are used to represent known quantities, and the last letters, unknown quantities. As a rule, small letters rather than capital letters are employed.

Alkali. In chemistry, a base that will dissolve in water is known as an alkali. See Base.

Alkaline Battery. See Edison Battery.

Alkaline Quenching Baths. See Quenching Baths, Alkaline.

Alladin. Welding rod suitable for welding white-metal die-castings that have formerly been considered unweldable. This rod is said to produce a weld that has as great strength as the base material. Used in welding shops for welding die-cast parts such as radiator grilles, lamp brackets, carburetor bowls, ornaments, and other die-cast products. Used with the oxy-acetylene flame.

Alligation. Alligation or "the rule of mixtures" are names applied to several rules of arithmetical processes for determining the relation between proportions and prices of the ingredients of a mixture and the cost of the mixture per unit of weight or volume. For example, if an alloy is composed of several metals varying in price, the price per pound of the alloy can be found as in the following example: An alloy is composed of 50 pounds of copper at 14 cents a pound, 10 pounds of tin at 29 cents a pound, 20 pounds of zinc at 5 cents a pound, and 5 pounds of lead at 4 cents a pound. What is the cost of the alloy per pound, no account being taken of the cost of mixing it? Multiply the number of pounds of each of the ingredients by its price per pound, add these products together, and divide the sum by the total weight of all the ingredients. The quotient is the price per pound of the alloy.

Allowance. The term "allowance," as applied to the fitting of machine parts, means a difference in dimensions prescribed in order to secure classes of fits; in other words, allowance is the amount required either above or below a nominal size, so that a certain class of fit is obtained, as, for example, a running fit, a forced or pressed fit, etc. For instance, if the hole in a crank disk is 3 inches in diameter and the shaft is made 3.005 inches in diameter in order to secure a forced fit, the 0.005 inch would represent the *allowance* for that part. The terms "allowance" and "tolerance" are often—but incorrectly—used interchangeably; according to common usage "tolerance" is a difference in dimensions prescribed in order to allow unavoidable imperfections of workmanship.

Alloy. An alloy is an intimate mixture of two or more metals melted together. Mixtures of this kind are generally mechanical in their nature, but are homogeneous; in some cases, they may form chemical compounds. As a rule, when two metals are melted together to form an alloy, the substance formed is, for all practical purposes, a new metal. Brass, bronze, and German silver are examples of well-known alloys.

Alloys, Acid-Resisting. See Acid-resisting Alloys.

Alloys, Die-Casting. See Die-casting Alloys.

Alloys, Non-Ferrous. Alloys may be divided into ferrous and non-ferrous; the former contain iron as their chief component, while the latter do not. The most important of the ferrous alloys are the alloy steels. Of non-ferrous alloys, the bronzes, brasses, aluminum, zinc, and copper alloys are the most important. *Bronze* is an alloy consisting of copper and tin in variable proportions, in which copper is the chief component. *Brass* is an alloy consisting of copper and zinc in variable proportions, with copper as the chief component. Besides bronze and brass, a classification of non-ferrous alloys that is used, but not universally adhered to, defines an alloy consisting of more than two metals with copper as the chief component as a *composition*. Thus a bronze composition is an alloy of copper and tin with one or more variable components, but in which tin is the chief minor component; a brass composition is an alloy of copper and zinc combined with one or more other components, but in which zinc is the chief minor ingredient. In general usage, brass and bronze compositions are frequently known simply as "brass" and "bronze."

Alloy Steel. A steel containing some metallic element other than iron and carbon, such as nickel, chromium, tungsten, vanadium, etc., is generally known as an "alloy" or "special" steel.

These various metals, when added to steel in certain (generally small) percentages, add distinct properties; they especially increase the hardness and the toughness of the steel. Various alloy steels are treated separately under their respective headings.

Almandite. See Garnet.

Alnico. Alloy containing iron, aluminum, nickel, and cobalt. Usually cast and finished to shape by grinding. Magnets made from this alloy have remarkable power and will lift sixty times their own weight. Applied to a variety of electrical uses, including blow-outs for relays, holding in magnets for large switches, special timing relays, and various control devices. Small motors and control devices formerly operated by electromagnets can be operated by Alnico permanent magnets at a great saving in cost.

Alowalt. The trade name "Alowalt" is used by the Waltham Grinding Wheel Company for aluminum-oxide products. See Aluminum Oxide.

Aloxite. The trademark "Aloxite" is used by the Carborundum Company for abrasives or other products made from aluminum oxide. See Aluminum Oxide.

Alsimag 222. Machinable, ceramic material with low dielectric loss at high frequencies which can be used at temperatures up to 2500 degrees F. Available in round or tubular form and in disks or plates; special shapes also can be supplied. Because of abrasive nature, must be machined with carbide tipped tools. Especially suitable for building working models. Also suitable for application in electronic field.

Alternating Current. An alternating electrical current is a current that alternates regularly in direction and, unless otherwise specified, the term "alternating current" refers to a periodic current with successive waves of the same shape and area. Alternating current has the advantage over direct current in that simpler generating machines, and generally more rugged motors, may be used; but the chief advantage is that it is possible to obtain and use very much higher voltages than can be easily obtained or used with direct current. Alternating current is, therefore, used whenever distant transmission of electric power is necessary.

Alternating-Current Generator. See Generator, Alternating-current.

Alternation. An *alternation* is an oscillation of an electric or magnetic wave from a zero to a maximum value and back to zero again. It may be positive or negative, positive alternations generally being indicated above the zero reference line, and the

negative, below. There are two alternations to each cycle. See Cycle, Alternating Current.

Alumina. Alumina or aluminum oxide, chemical formula Al_2O_3, occurs in nature in the mineral *corundum.* The alumina in corundum is the abrasive material which makes it useful for abrasive purposes. The abrasive material in *emery* is also alumina. See also Aluminum Oxide.

Aluminum. Aluminum is widely distributed in nature in combinations, especially as silicates, but is never found in the free state. Alumina or aluminum oxide, from which aluminum is obtained, was first discovereed by Marggraf, in 1754. The metal itself, however, was first discovered by Wohler, in 1828, but it was not until about 1883 that aluminum was produced on a commercial scale. Now aluminum is produced by electrical means from bauxite, a hydrated oxide of aluminum (Al_2O_3 + 2 H_2O). This mineral is widely distributed all over the world, but the most important places where it is found are in Alabama, Arkansas, and Georgia, and in the south of France and the north of Ireland. Aluminum is also contained in various other natural compounds, such as corundum, cryolite, and kaolin or china-clay.

Properties of Aluminum: Aluminum is a white metal having a somewhat bluish luster when polished. The specific gravity of aluminum varies from 2.5 to 2.7. When cast in the pure state, it has a specific gravity of 2.58. When rolled in bars of large section, the specific gravity is about 2.6, but, when rolled into very thin sheets, it may rise to 2.69. Commercial aluminum, however, contains impurities to such an extent that the specific gravity generally varies between 2.7 and 2.8. When in the molten state, the metal expands and the specific gravity is only from about 2.43 to 2.54. As pure aluminum is lighter than the commercial product, a careful determination of the specific gravity is a good indication of the purity of the metal tested.

Aluminum is a very ductile and malleable metal; it can be made into sheets 0.000025 inch thick and drawn into wires 0.004 inch in diameter. Sheets as thin as mentioned can only be obtained by beating like gold-leaf, but sheets may be rolled down to a thickness of 0.0005 inch. The melting point of aluminum is at 1218 degrees F. (659 degrees C.). The coefficient of linear expansion, by heat, is 0.0000125 per each degree F. The mean specific heat between 32 and 212 degrees F. is 0.227, and the latent heat of fusion, 28.5 B.T.U. Aluminum is a good conductor of heat and is surpassed, in this respect, only by silver, copper, and gold. Its conductivity of heat is equal to 31 per cent of that of silver. The heat transmitted in British thermal units per second, through aluminum 1 inch thick, per square

inch of surface, for a temperature difference of 1 degree F., is 0.00203 B.T.U.

Aluminum is a good conductor of electricity, its electrical conductivity being about 60 per cent of that of copper for equal volumes, or about double that of copper for equal weights. Aluminum is not magnetic. Pure aluminum, chemical symbol Al, and atomic weight 27.1, has a hardness on the Mohs scale of 2.5, this degree of hardness making it just a little too hard to be scratched by the finger nail. Impurities, however, harden the metal to a considerable extent, even when present in small quantities, and the purity of the metal is roughly estimated by the ease with which it can be cut with a steel knife. The surface of aluminum is hardened, to a very great degree, by cold-drawing or rolling, so that the surface may obtain a hardness equal to that of brass. The numerous aluminum alloys are distinguished by their low specific gravity and high tensile strength.

Aluminum Alloys. While aluminum is valuable for many light-weight machine parts, it is soft and lacking in tensile strength and rigidity for many purposes. In order to increase the strength, and at the same time retain the valuable property of lightness, copper, manganese, iron, and nickel have been alloyed with aluminum in various proportions. By adding from 2 to 8 per cent of any of these metals, an alloy is obtained having a strength and hardness far superior to that of aluminum. Plates and bars made from these alloys have ultimate tensile strengths varying from 40,000 to 50,000 pounds per square inch with an elastic limit of from 55 to 60 per cent of the ultimate tensile strength, an elongation of 20 per cent in 2 inches, and a reduction of area of 25 per cent. As the percentage of the heavier metals that is added to the aluminum is small, the specific gravity can be kept well below 3. In fact, most of these alloys have a specific gravity of from 2.8 to 2.85. In castings, the percentage of alloying metal that must be added is greater than in plates and bars. The ultimate tensile strength of aluminum alloy castings containing zinc, iron, manganese, or copper varies from 20,000 to 25,000 pounds per square inch. If tin is added to the alloy, the shrinkage is reduced, and certain aluminum-tin alloys have less shrinkage than cast iron. There are a number of aluminum alloys that are known by specific trade names. See also Duralumin.

Aluminum-copper Alloys: Aluminum-copper alloys are made in two series, one of which contains from 2 to 10 per cent of copper with the remainder aluminum, and another which contains from 3 to 10 per cent of aluminum with the remainder copper. The latter alloys, being high in copper, are known as *aluminum bronzes.* The series of alloys high in aluminum can

be rolled into bars and made into castings. The specific gravity varies from 2.71 with 2 per cent of copper, to 2.84 with 8 per cent of copper; the tensile strength for a 2-per-cent copper alloy is 43,000 pounds per square inch; for a 6-per-cent copper alloy, 45,000 pounds per square inch; and for an 8-per-cent alloy, 56,000 pounds per square inch. The copper and aluminum in this series of alloys will separate in the cooling, and chilled molds are therefore necessary, so that the metals will not have time to separate before they solidify. The pouring of these alloys should be done at the lowest possible temperature. Just before pouring, the molten metal should be stirred with a carbon rod.

Aluminum-zinc Alloys: Alloys of aluminum and zinc are valuable in that they resist corrosion effectively. The addition of zinc to aluminum facilitates the production of good castings. While these metals will alloy in all proportions, only alloys containing from 15 to 33 per cent of zinc are in general use. Alloys containing less than 15 per cent of zinc are malleable and can be rolled and drawn, but the tensile strength is inferior. If dynamic as well as tensile strength is desired, the alloy should not contain less than 20 per cent of zinc. With 15 per cent of zinc, the tensile strength is about 22,000 pounds per square inch; the elastic limit, about 16,000 pounds per square inch; the elongation in two inches, 6 per cent; and the reduction of area, 10.5 per cent. An alloy of zinc and aluminum containing 25 per cent of zinc can be rolled into bars and drawn into wire, and is probably the zinc-aluminum alloy most generally used. When cast in sand molds, this alloy has a tensile strength of 27,000 pounds per square inch; an elongation in two inches of 1 per cent; and a reduction in area of 3 per cent; the specific gravity is 3.4. Chilled castings have been made having a tensile strength of 40,000 pounds per square inch. Alloys containing from 10 to 30 per cent of zinc can be easily worked in machine tools and, in most cases, without cutting lubricants. The addition of a small percentage of copper to aluminum-zinc alloys greatly increases the tensile strength. One disadvantage of the aluminum-zinc alloys is that they lose their strength rapidly with rising temperature; even an increase of 100 degrees F. over ordinary room temperature produces a marked effect.

Aluminum Alloys, Cast. The S.A.E. standard cast aluminum alloys are of two types. *Type 1:* Improvement in the physical properties of Type 1 results from alloying only. *Type 2:* The properties of Type 2 that result from alloying, are further improved by heat-treatment.

In the design of patterns for the production of aluminum alloy sand castings, a shrinkage of 0.156 (5/32) inch per foot is

usually allowed, although this value may vary slightly, depending upon the form and size of the casting.

S.A.E. Standard No. 30, Type 1 Alloy: This alloy, known in the trade as No. 12, is used for general casting purposes. It formerly was used for most of the castings produced from aluminum alloys. The use of this alloy has declined due to the development of other compositions such as Nos. 33 and 36.

Composition of No. 30: Copper, 7.00 to 8.50; zinc, max., 0.20; silicon, iron, zinc, manganese and tin, max., 1.70; other impurities, 0.00 per cent; aluminum, remainder.

Physical Properties: Tensile strength, not less than 18,000 pounds per square inch; specific gravity, approximately 2.83. The properties of this and other cast aluminum alloys apply to standard tension test specimens separately cast, and tested without machining.

S.A.E. Standard No. 31, Type 1 Alloy: This composition is used very little in the United States but extensively in Europe as a general casting alloy. The applications are similar to those of Nos. 30, 33, and 36. It is not recommended for use at elevated temperatures nor under conditions conducive to corrosion.

Composition of No. 31: Copper, 2.25 to 3.25; zinc, 12.50 to 14.50; silicon, iron, manganese and tin, max., 170; other impurities, 0.00 per cent; aluminum, remainder.

Physical Properties: Tensile strength, not less than 25,000 pounds per square inch; specific gravity, approximately 3.

S.A.E. Standard No. 31A, Type 1 Alloy: This alloy is used where somewhat higher mechanical properties are required than are obtained with Nos. 30, 33, and 36. It is not recommended for use at elevated temperatures nor under conditions conducive to corrosion.

Composition of No. 31A: Copper, 2.0 to 3.5; zinc, 9.0 to 11.5; iron, 1.25 to 1.75; other impurities, max., 1.0 per cent; aluminum, remainder.

Physical Properties: Tensile strength, not less than 25,000 pounds per square inch; specific gravity, about 3.

S.A.E. Standard No. 322, Type 2 Alloy: This alloy is used for water-cooled cylinder heads for automotive or aircraft engines and for similar applications requiring sound leak-proof castings produced either in sand or permanent metal molds. This alloy has excellent foundry characteristics and resistance to corrosion.

Composition of No. 322: Silicon, 4.5 to 5.5; copper, 1.0 to 1.5; magnesium, 0.4 to 0.6; iron, max., 0.5; other impurities, max., 0.3 per cent; aluminum, remainder.

Physical Properties: This alloy can be heat-treated to improve

its mechanical properties. The minimum tensile strength ranges from 27,000 to 36,000 pounds per square inch, depending upon heat-treatment.

S.A.E. Standard No. 320, Type 1 Alloy: This alloy is used for carburetor cases, cast pipe fittings, and other castings requiring high resistance to corrosion. It has good mechanical properties and is easily machined.

Composition of No. 320: Magnesium, 3.25 to 4.25; manganese, max., 0.60; iron, max., 0.30; silicon, max., 0.25; copper, max., 0.10; all elements other than aluminum, magnesium and manganese, max., 0.60 per cent; aluminum, remainder.

Physical Properties: Tensile strength, 22,000 pounds per square inch minimum; specific gravity, about 2.64 (less than that of pure aluminum).

S.A.E. Standard No. 321, Type 2 Alloy: This alloy is used for automobile engine pistons because of its low coefficient of expansion compared with other aluminum alloys, its hardness and resistance to wear, and its good mechanical properties at elevated temperatures. The pistons are as a rule cast in permanent metal molds but this alloy may also be used for sand castings and for other applications similar to those for Nos. 34 and 39.

Composition of No. 321: Silicon, 11.25 to 15.0; magnesium, 0.7 to 1.3; nickel, 1.0 to 3.0; copper, 0.5 to 1.5; iron, max., 1.3; other impurities, max., 0.3 per cent; aluminum, remainder.

S.A.E. Standard No. 323, Type 2 Alloy: This alloy has excellent foundry characteristics and resistance to corrosion. It is commonly used for high-strength castings which are too intricate to permit using alloy No. 38. It is also preferred where high corrosion resistance is necessary.

Composition of No. 323: Silicon, 6.5 to 7.5; magnesium, 0.2 to 0.4; iron, max., 0.5; copper, max., 0.2; other impurities, max., 0.3 per cent; aluminum, remainder.

Physical Properties: Tensile strength, 26,000 to 30,000 pounds per square inch minimum, depending upon heat-treatment.

S.A.E. Standard No. 324, Type 2 Alloy: This alloy is used for castings requiring a maximum ratio of strength to weight. It is used for some aircraft fittings, truck parts, and especially where service conditions are severe.

Composition of No. 324: Magnesium, 9.25 to 11.25; copper, max., 0.20; iron, max., 0.30; silicon, max., 0.20; other impurities, max., 0.20 per cent; aluminum, remainder.

Physical Properties: Minimum tensile strength, 40,000 pounds per square inch; specific gravity, about 2.55 compared with 2.70 for pure aluminum.

S.A.E. Standard No. 33, Type 1 Alloy: This is widely used as a general casting alloy and for such parts as crankcases, oil-pans,

differential carriers, transmission cases, camshaft housings, cylinder heads for water-cooled automobile engines.

Composition of No. 33: Copper, 6.0 to 8.0; zinc, max., 2.5; iron, max., 1.5; silicon, max., 2.0; other impurities, max., 1.0 per cent; aluminum, remainder.

Physical Properties: Minimum tensile strength, 19,000 pounds per square inch; specific gravity, from 2.83 to 2.86. If cast in permanent molds, the minimum tensile strength will be about 23,000 pounds per square inch.

S.A.E. Standard No. 34, Type 2 Alloy: This alloy has been used chiefly for pistons of automobile engines (like No. 321). It is also used for camshaft bearings, valve tappet guides, and other parts requiring hardness and resistance to wear. It is used principally for permanent mold castings but is also cast in sand. Air-cooled cylinder heads for aircraft engines and valve guides and piston sleeves for Diesel engines are other examples of applications.

Composition of No. 34: Copper, 9.25 to 10.75; iron, max., 1.50; iron plus silicon, max., 2.0; magnesium, 0.15 to 0.35; zinc, max., 0.20; all other elements, max., 0.60 per cent; aluminum, remainder.

Physical Properties: Minimum tensile strength, from 26,000 to 34,000 pounds per square inch for permanent mold castings. The sand cast alloy should have a tensile strength of at least 23,000 pounds per square inch, and this may be increased by heat-treatment to a minimum of 30,000 pounds per square inch.

S.A.E. Standard No. 35, Type 1 Alloy: This alloy is used for general casting purposes, particularly for large intricate castings having both thin and heavy sections, or for castings which must be leak-proof under pressure. It has good resistance to salt spray corrosion. It is used for automobile body parts, manifolds, instruments, and a variety of parts not requiring the higher mechanical properties of a Type 2 alloy.

Composition of No. 35: Silicon, 4.5 to 6.0; copper, max., 0.4; iron, max., 0.8; zinc, max., 0.2; titanium, max., 0.2; manganese, max., 0.3; magnesium, max., 0.05; other impurities, max., 0.3 per cent; aluminum, remainder.

Physical Properties: Minimum tensile strength, 17,000 pounds per square inch for sand castings, and 21,000 pounds per square inch for metal mold castings; specific gravity, 2.65 to 2.66.

S.A.E. Standard No. 37, Intermediate Alloy: Applications of this alloy are similar to those of No. 35 which it surpasses in mechanical properties. It has good foundry characteristics and resistance to salt spray corrosion.

Composition of No. 37: Silicon, 12.0 to 13.0; iron, max., 0.8; copper, max., 0.3; zinc, max., 0.2; manganese, max., 0.5; mag-

nesium, max., trace; other impurities, max., 0.3 per cent; aluminum, remainder.

Physical Properties: Minimum tensile strength, 24,000 pounds per square inch; elongation in 2 inches, 4 per cent minimum.

S.A.E. Standard No. 38, Type 2 Alloy: This alloy is used for windshield frames; fire engine, motor coach and aircraft engine crankcases; and a variety of other parts in both motor vehicle and aircraft assemblies where high strength and light weight are essential. It has good resistance to salt spray corrosion and is extensively used in the manufacture of outboard motors and for certain castings used on ships.

Composition of No. 38: Copper, 4.0 to 5.0; silicon, max., 1.2; iron, max., 1.2; manganese, max., 0.3; magnesium, max., 0.05; zinc, max., 0.2; other impurities, max., 0.2; all constituents other than aluminum and copper, max., 2.5 per cent.

Physical Properties: One of three heat-treatments may be applied, depending upon properties required. Minimum tensile strength ranges from 29,000 to 36,000 pounds per square inch, depending upon heat-treatment; the specific gravity is about 2.77.

S.A.E. Standard No. 39, Type 2 Alloy: This alloy is used for pistons and cylinder heads of aircraft engines and for other castings subjected to elevated temperatures. It may be used as cast but usually is heat-treated to develop higher physical properties or to relieve casting strains and stabilize dimensions at elevated temperatures.

Composition of No. 39: Copper, 3.75 to 4.25; nickel, 1.8 to 2.3; magnesium, 1.2 to 1.7; iron, max., 1.0; silicon, max., 0.7; other impurities, max., 0.2 per cent; aluminum, remainder.

Physical Properties: Minimum tensile strength for sand castings, 23,000 pounds per square inch which may be increased to 30,000 by heat-treatment. If cast in permanent molds, the minimum tensile strength is 26,000 pounds per square inch which may be increased to 40,000 by heat-treatment. Specific gravity is about 2.73 to 2.77, the higher values being for permanent mold castings.

Aluminum Alloys, Wrought. S.A.E. standard specifications for wrought alloys as given in the following indicate fabricated forms which are regularly manufactured. Type 1 indicates an improvement in the physical properties resulting from alloying only. Type 2 indicates that the properties resulting from alloying are further improved by heat-treatment.

S.A.E. Standard No. 20, Type 1 Alloy: This alloy (commercial designation 4S) is manufactured in the form of sheets, bars, rods, wire, and extruded shapes. The sheets and plates are used for panels on buses and trucks and for cowling and similar aircraft applications. Tubing is used for fuel and oil lines on aircraft

and automobiles and for windshield wiper tubing. The range of tensile strength in the "soft" to "hard" tempers is from 29,000 to 38,000 pounds per square inch, minimum.

Composition of No. 20: Magnesium, 0.9 to 1.4; manganese, 0.9 to 1.4; copper, max., 0.2; aluminum, min., 96.0 per cent.

S.A.E. Standard No. 24, Type 2 Alloy: This alloy, in the form of sheets, plates, tubing, bars, rods, rivets, and in rolled and extruded shapes, is replacing No. 26 to an increasing extent in the construction of aircraft because of its high physical properties. The commercial designation is 24S. In the form of sheets, the tensile strength varies from 35,000 for soft temper to 62,000 pounds per square inch for heat-treated sheets.

Composition of No. 24: Copper, 3.6 to 4.7; magnesium, 1.25 to 1.75; manganese, 0.3 to 0.9; aluminum, min., 92.0 per cent.

S.A.E. Standard No. 25, Type 1 Alloy: This specification applies to commercially pure aluminum sheets and strips. These aluminum sheets have excellent forming qualities and can readily be spun, stamped, or drawn into desired shapes. Aluminum of commercial purity is manufactured in practically all forms, such as bars, rods, wire, tubing, extruded shapes, etc. The tensile strength of flat sheets varies from about 14,000 to 22,000 pounds per square inch minimum, depending upon the temper.

Composition of No. 25: Aluminum, min., 99.0 per cent.

S.A.E. Standard No. 26, Type 2 Alloy: This alloy is commonly known as duralumin, dural, or 17S. It is commercially available in sheets, tubing, bars, wire, etc., and in both rolled and extruded forms, including standard structural shapes. It is used for bolts and nuts, machine screws, wood screws, rivets, forgings, screw machine products, fuel and lubrication tube fittings, etc. The minimum tensile strength of heat-treated sheets and plates is about 55,000 pounds per square inch.

Composition of No. 26: Copper, 3.5 to 4.5; magnesium, 0.2 to 0.75; manganese, 0.4 to 1.0; aluminum, min., 92.0 per cent.

S.A.E. Standard No. 27, Type 2 Alloy: This alloy is especially adapted to forging because of its excellent hot-working properties. The forgings in common use include connecting-rods for automotive engines, crankcases, airplane propellers, automobile hardware, miscellaneous fittings. The commercial designation is 25S. This alloy in the form of sheets and plates is used less than the S.A.E. Nos. 24 and 26. The minimum tensile strength for forgings is about 55,000, and the yield strength 30,000 pounds per square inch.

Composition of No. 27: Copper, 3.9 to 5.0; manganese, 0.5 to 1.1; silicon, 0.5 to 1.1; aluminum, min., 92.0 per cent.

S.A.E. Standard No. 28, Type 2 Alloy: As this alloy can be formed hot readily, it is used for making complicated forgings

which might be difficult to produce with alloys Nos. 26 or 27. The commercial designation of No. 28 is 51S. It is available in various forms, including extruded shapes. In the fully heat-treated temper, the minimum tensile strength varies from 40,000 to 45,000 pounds per square inch.

Composition of No. 28: Magnesium, 0.45 to 0.9; silicon, 0.6 to 1.2; aluminum, min., 96.3 per cent.

S.A.E. Standard No. 29, Type 1 Alloy: This alloy is used instead of commercially pure aluminum when somewhat greater strength and hardness are required. The forming qualities are nearly the equal of commercial aluminum except for deep drawing and spinning. In the form of sheets, it is used for aircraft tanks and automobile body panels, although harder alloys are preferred in some plants. The tensile strength of flat sheets varies from 19,000 to 27,000 pounds per square inch for soft to hard tempers.

Composition of No. 29: Manganese, 1.0 to 1.5; copper, max., 0.2; aluminum, min., 97.0 per cent.

Aluminum Annealing. Correct annealing of aluminum is dependent upon both time and temperature. Frequently the length of the annealing period has a more important bearing on the mechanical properties than has the temperature. Although aluminum is distinctly a malleable metal, it frequently is necessary to anneal it two or three times during the forming of an intricate piece. The procedure is to work the piece to a certain stage, anneal it, and repeat the process until the desired shape is obtained. Sheet aluminum can be annealed most efficiently in a muffle furnace, where the heat can be obtained by radiation. If such a furnace is not available, the work may be annealed quite satisfactorily in an open fire of clean coke, over a brazier's gas hearth, or over the flame of the benzoline or gasoline blow-torch. Owing to the relatively low melting point of aluminum, which is approximately 1218 degrees F., great care must be taken during annealing to prevent the metal from melting. The annealing temperature varies from 700 to 900 degrees F., depending on the thickness of the metal and the length of time that it is subjected to the heat. Tests have shown that short exposures in the annealing temperature, ranging from three to thirty minutes, confer workable properties on the metal.

Aluminum Brass. This alloy consists of 70.5 per cent of copper; 26.4 per cent of zinc; and 3.1 per cent of aluminum. It is used in cases where an accurately-sized casting is required. The alloy can also be rolled and forged hot, when the aluminum content does not exceed that specified. In aluminum brasses where the percentage of aluminum exceeds 4 per cent, it cannot be worked easily. The tensile strength of aluminum brass is about

42,000 pounds per square inch with an elastic limit of about 17,000 pounds per square inch, and an elongation of 50 per cent.

Aluminum Bronze. This is one of a number of alloys in which aluminum is alloyed in small percentages with another metal which forms the base. It contains from 5 to 11 per cent of aluminum, the remainder being copper, and is a very dense, fine-grained and strong alloy. With 10 per cent of aluminum, forged bars will have a tensile strength of 100,000 pounds per square inch and an elastic limit of 60,000 pounds per square inch, with an elongation of 10 per cent in 8 inches, and a specific gravity of about 7.5. If from 5 to 7.5 per cent of aluminum is used, the specific gravity will be from 8 to 8.30, with a tensile strength of from 78,000 to 80,000 pounds per square inch, an elastic limit of 40,000 pounds per square inch, and an elongation of 30 per cent in 8 inches. Alloys containing 95 per cent of copper and 5 per cent of aluminum have a tensile strength of about 55,000 pounds per square inch and an elastic limit of about 25,000 pounds per square inch. The values for tensile strength given above for aluminum bronzes are based upon tests with specially high-grade material made from very pure metals and cannot be expected to be obtained in all cases in the commercial brass foundry. It is safe to say, however, that aluminum bronzes will have a tensile strength of from 40,000 to 60,000 pounds per square inch with an elongation of from 10 to 20 per cent in 8 inches. Aluminum bronze can be drawn into wire which is used for electrical resistance coils. The alloy withstands intense heat for an unlimited time without injury. If more than 11 per cent of aluminum is added to copper, the alloy is too brittle to be of any commercial value. With an aluminum content of about 9 or 10 per cent, the best all-around results are obtained.

Aluminum Bronze, Cast. This alloy has considerable strength, resistance to corrosion, hardness equal to manganese bronze, and good bearing qualities under certain conditions. The S.A.E. Standard No. 68 is used for worm-wheels, gears, valve guides, valve seats, and forgings.

Composition of No. 68: Copper, (Grade A) 87 to 89, (Grade B) 89.50 to 90.50; aluminum, (Grade A) 7 to 9, (Grade B) 9.50 to 10.50; iron, (Grade A) 2.50 to 4, (Grade B) not over 1; tin, max., (Grade A) 0.5, (Grade B) 0.2; total other impurities, (Grade A) 1, (Grade B) 0.5 per cent.

Physical Properties: Tensile strength, (Grades A and B) as cast, 65,000 pounds per square inch; tensile strength, (Grade B) as heat-treated, quenched and drawn, 80,000 pounds per square inch; yield point, (Grades A and B) as cast, 25,000 pounds per square inch; yield point, (Grade B) as heat-treated, 50,000 pounds per square inch.

Aluminum Bronze, Wrought. This alloy has great strength, high resistance to corrosion, and a hardness equal to manganese bronze. It has good bearing and anti-friction properties and is used for gears, forgings, hot-forged valve seats and bushings for internal-combustion engines. The 10 per cent alloy can be heat-treated in a manner similar to steel. The physical properties improve somewhat by heating and quenching.

Composition of S.A.E. Standard No. 701: Copper, 88 to 95; aluminum, 4.5 to 10; iron, max., 4; other additions including nickel, tin and manganese, max., 2; other impurities including zinc and lead, max., 0.25 per cent.

Physical Properties: The ultimate strength (pounds per square inch) of rods and bars varies from 72,000 to 80,000; and plates, sheets and strips, from 50,000 to 60,000. The yield point of rods and bars (pounds per square inch) varies from 30,000 to 40,000; and plates, sheets and strips, from 20,000 to 24,000. This material must withstand cold bending without fracture through an angle of 120 degrees around a pin, the radius of which is equal to the diameter or thickness of the material.

Aluminum Die-Casting Alloy. See Die-casting Alloy, Aluminum-base.

Aluminum Discovery. The discovery of aluminum is generally credited to Wohler in 1827, but the claim has also been made that the metal was first prepared by Oersted in 1825. Results of certain experiments made by Oersted were published in the early part of 1825, and a specimen of the new metal was presented to the Danish Society of Sciences at that time. In 1826, Oersted published a paper in which he described the properties of the metal that he had obtained, stating that it had a distinct metallic luster.

Aluminum, Gun-Metal Finish. See Gun-metal Finish on Aluminum.

Aluminum-Monel. When a small percentage of aluminum is added to Monel metal, the alloy becomes non-magnetic. This alloy possesses great strength. Used for airplane parts located close to the compass, and for struts and guide wires on airplanes.

Aluminum Oxide. Artificial abrasives of the aluminum oxide class are produced in electric furnaces from bauxite, which is a soft earth, and is the purest form of aluminum oxide found in nature. The oxide crystallizes when bauxite is fused in the electric arc furnace, and because of the abrasive being artificially produced, undesirable elements can be eliminated. It is due to this fact that artificial abrasive wheels have become popular. Crystalline aluminum oxide ranges in color from white to deep wine color. Wheels made from this abrasive are recommended

for grinding materials having a high tensile strength, including the various steels, annealed malleable iron, wrought iron, tough bronzes and tungsten. Aluminum oxide grains are hard, tough, and dense, and when fractured, leave sharp cutting edges. The aluminum oxide abrasives have various trade names such as "Adamite," "Alowalt," "Aloxite," "Alundum," "Alu-lion," "Aluminox," "Bikorund," "Borite," "Boro-Carbone," "Borolon," "Coralox," "Corowalt," "Corundite," "Electrit," "Electrorubin," "Lionite," "Natite," "Staralox," "Sterlith," "Veral."

Aluminum Paint. Aluminum paint is opaque to sunlight and possesses high heat and light reflecting qualities. The high light reflectivity makes the paint particularly satisfactory for painting dark buildings, rooms, mills, etc. High reflectivity also means low absorption; therefore, when a tank or other chamber should be kept cool inside, this is facilitated by painting the outside with aluminum paint. It is the reason that an increasing number of gas and oil storage tanks and oil-tank cars are being painted with aluminum paint. In investigations conducted on oil storage tanks in the southwest, by the United States Bureau of Standards, it was found that the temperature of oil in tanks coated with aluminum paint was several degrees lower than in tanks coated with other paints. Furthermore, due to the lower temperature, there is a much smaller loss of the highly volatile oils from tanks coated with aluminum paint. It is evident from the foregoing that aluminum paint should not be used on radiators. See Radiation of Heat.

Aluminum Soldering. Some fractured and defective aluminum alloy castings can be repaired quite satisfactorily by the oxy-acetylene process, but often it is undesirable to heat the parts to the relatively high temperature necessary for welding, because of the resulting distortion. In such cases, a means of joining the parts without heating them to a high temperature is desirable. Aluminum parts can be permanently repaired by soldering when the solder can be made to adhere to the aluminum and when the joint thus made is not subject to deterioration. Aluminum cannot be soldered by the same process as that which the tinsmith uses in soldering tin and copper with a hot copper bit and a solder that will flow and follow the copper. The practice with aluminum is more like brazing with hard solders.

A solder joint in aluminum, on exposure to moisture, will not remain permanent, as galvanic cells are set up which cause the joint to become rapidly disintegrated by auto-corrosion. One of the most severe tests to which a solder joint can be subjected is that of placing it in steam; hence solder joints should be protected against corrosion by a bitumastic paint or varnish.

Aluminum Solder: A suitable solder for joining aluminum may be composed solely of tin and zinc, the amount of zinc employed ranging, perhaps, from 15 to 50 per cent. Another solder for aluminum consists of a mixture of tin, zinc, and aluminum. In this mixture, the amount of zinc may vary from 8 to 15 per cent, and the aluminum from 5 to 12 per cent. The tensile strength of a good aluminum solder is about 7000 pounds per square inch. It is desirable that the solder should not be brittle and it is best applied without a flux.

The process of tinning is accomplished by heating the surfaces to be joined with an atmospheric gas torch or a kerosene blow-torch, to a temperature somewhat above the fusing point of the solder, and then rubbing the surface with the point of a tinned steel tool which serves to remove the outside film and allows the solder to act upon the clean surface. The higher the temperature —within certain limits—at which the tinning is done, the better will be the adhesion of the tinned layer. After the surfaces to be joined have been properly tinned, they are joined by pressing them together and again heating to the required temperature, as determined by the composition of the solder. If necessary, the joint may be smoothed with a spatula just before the solder hardens, care being taken not to move the work until the solder has become thoroughly set.

Aluminum Welding. The successful welding of aluminum alloy castings by the oxy-acetylene process, depends a great deal upon the success achieved in breaking down the aluminum oxide, the forming of which is intensified as soon as the oxy-acetylene torch flame comes in contact with the metal. It is this oxide film that prevents the proper flow of the metal at the welding temperatures and that has been the cause of many failures in aluminum welds.

Cleaning Surfaces: The surfaces to be joined must be thoroughly cleaned and the material near the surfaces to be welded must also be clean, as otherwise the impurities near the joint will invariably set up auto-corrosion in the weld. Oily machine parts should be allowed to remain for a few seconds in a hot 10 per cent caustic soda solution, after which, the castings should be thoroughly washed and scrubbed in plenty of clean hot water. It is often advisable first to wash the oily castings with gasoline to remove the greater part of the grease and dirt.

Joint Beveling: After the work is cleaned, a V-shaped groove is filed or chipped along the crack or seam to the bottom to permit the metal to be melted the full depth of the work. However, aluminum alloy castings up to ¼ inch in thickness can be welded with the torch flame without beveling the joints.

Preheating: In welding aluminum and aluminum alloy cast-

ings, it is necessary to preheat and anneal the work in order to prevent too rapid expansion and contraction of the metal. Preheating also conserves gas, increases the rate of welding, and prevents warping. Great care, however, must be exercised to avoid exceeding a temperature of 750 and 840 degrees F., respectively, when preheating and reheating or annealing the work. At higher temperatures a piece of work may be rendered useless by deformation. During the preheating of castings of complex shape or castings that vary greatly in thickness, the casting should be covered with sheet asbestos to keep the temperature as uniform as possible. The asbestos should not be removed during the welding operation, except as it is necessary to effect the weld.

Welding Procedure: A puddling rod, made from a piece of mild steel rod 3/16 or ¼ inch in diameter and flattened on one end like a flat scraper, is used in welding to scrape and agitate the metal at the moment of melting in order to break up the oxide and allow the molten metal to flow together. It is necessary to wipe the puddling rod frequently to prevent it from becoming coated with oxide, and care must be taken not to allow it to reach a red heat, as otherwise oxide of iron will be formed on it which might result in a defective weld. The oxide formed in the course of melting aluminum offers considerable resistance to the welding flame, and it must be eliminated to effect a homogeneous weld. This is best done by employing an aluminum alloy welding flux which dissolves and deoxidizes the layer of oxide adjacent to the joint to be welded, at the temperature at which the aluminum reaches a molten state.

The welding material, usually a rod or broken aluminum part, should be of as pure aluminum as it is possible to obtain and the end of the rod should be kept in the molten bath while welding. For aluminum alloy castings, the welding material should be of approximately the same composition as the alloy to be welded.

Flame Adjustment: In making a weld, the torch flame should be so adjusted that it will furnish a slight excess of acetylene, and it is essential to avoid contact of the white-hot bulb of cone with the metal that is about to become molten, because the hot temperature in this part of the flame tends to produce holes in the metal which are often difficult to repair. The correct distance varies according to the size of torch tip employed, but in general, the distance should be from ¼ to ¾ inch. After welding, the casting should be reheated evenly and allowed to cool very slowly. When the casting is cold, it should be thoroughly washed in hot water to remove all traces of the flux, which would otherwise continue to produce a chemical action on the metal that would result in harmful corrosion.

Aluminum Welding Fluxes. The oxide formed in the course of melting aluminum offers considerable resistance to the welding flame. It does not always rise to the surface, especially if the work is thick, yet it must be eliminated to effect a homogeneous weld. This is done by employing a flux which dissolves and deoxidizes the layer of oxide adjacent to the joint to be welded, at the temperature at which the aluminum reaches a molten state. Another function of a flux is to protect the fused metal from contact with the air.

An example of a good flux for aluminum and aluminum alloys with a melting point of approximately 1110 degrees F. is one containing a mixture of lithium chloride, potassium chloride, potassium bisulphate, and potassium fluoride. The reactions that take place in the application of such a flux are believed to be as follows: The potassium fluoride reacts with the potassium hydrogen sulphate, forming hydrofluoric acid, and this immediately acts on the aluminum oxide, forming aluminum fluoride, which is free to combine with the excess of potassium fluoride existing in the flux, forming potassium aluminum fluoride, which is capable of dissolving a further quantity of aluminum oxide. The lithium chloride and potassium chloride serve the purpose of lowering the fusion point of the mixture.

When castings that have sand on their surface are to be welded, a flux that will remove the sand must be used. If the sand is not removed, it is in part reduced, resulting in silicon being passed into the metal — a condition that often reduces the strength of the weld an appreciable amount. A flux that is adapted for use under these conditions is composed of potassium chloride or fluorspar. This flux will prevent silicon from entering the alloy.

The flux may be applied in paste form to the surfaces to be welded, or the parts may be heated and the powdered flux sprinkled over the joint, or the end of the welding rod may be heated and dipped into the flux, which readily adheres to it in the form of a thin varnish; the last method is the safest and best. The powdered fluxes should be kept free from dust and dirt, and preferably in air-tight containers, as they absorb moisture rapidly.

Alundum. "Alundum" is the registered Norton Company trade-mark designating all brands of aluminum oxide abrasive as well as all refractory and laboratory ware, and other products derived from these materials. In general, Alundum abrasive is used for grinding materials of high tensile strength— materials that are hard, yet tough and strong.

Amalgams. Alloys formed by mercury and other metals are known as "amalgams." Many of these are formed by direct contact of a metal with mercury; others are formed when the metal and mercury are placed together in dilute acid. In still other cases, mercury is added to the solution of a metallic salt, or the metal is added to the solution of mercury nitrate. When newly made, amalgams are plastic, but they harden after a short time and then usually either expand or contract to a considerable extent. The most common metals that combine with mercury to form amalgams useful in the industries are tin, copper, cadmium, bismuth, silver, and gold. Tin amalgam is used for silvering mirrors. Copper and cadmium amalgams are used in dentistry, silver and gold amalgams are used in silvering and gilding, and an amalgam of zinc and tin is used in electrical machinery. Zinc plates of electric batteries are covered with an amalgam in order to reduce the polarization. Many amalgams are useful as cements for metals, the cement being applied in its plastic form when newly made, and hardening after a short interval, as mentioned.

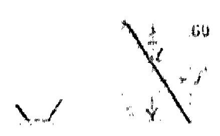
American Standard Screw Thread System. The American Standard screw thread is a development of the older U. S. Standard which it has superseded. The American Standard is the same as the U. S. Standard so far as thread form or profile is concerned. The number of threads per inch for a given diameter is also the same, with the exception of diameters above 2¾ inches. According to the American Standard, screw threads from 2½ to 4 inches, inclusive, all have 4 threads per inch. According to the older U. S. Standard, the 3- and 3¼-inch diameters have 3½ threads per inch; the 3½-inch diameter, 3¼ threads per inch; and the 3¾- and 4-inch diameters, 3 threads per inch. The present American Standard does not extend beyond the 4-inch diameter. The U. S. Standard includes diameters up to 6 inches.

Series of Pitches: The American Standard has five series of pitches known as the Coarse-thread Series, the Fine-thread Series, the 8-Pitch, 12-Pitch and 16-Pitch Series. In the Coarse- and Fine-thread series, the numbers of threads per inch decrease as the diameters increase. In the 8-Pitch Series, all diameters included have 8 threads per inch; similarly, all diameters in the 12-Pitch Series have 12 threads per inch, and, in the 16-Pitch Series, 16 threads per inch. The Coarse-thread and Fine-thread series (especially the former) are intended for general application, whereas the 8-pitch, 12-pitch and 16-pitch series are more special. For example, the 8-pitch series is intended for such parts as cylinder head studs, bolts for high-pressure pipe flanges, or similar fastenings requiring an initial

tension and a pitch that remains the same for all diameters. The 12-pitch series is used in boiler practice and also in machine construction for thin nuts on shafts and sleeves. The 16-pitch series is intended mostly for threaded adjusting collars, bearing retaining nuts, or any other applications requiring a fine thread.

Symbols Used in Specifying American Standard: If the drawing calls for a 1½-inch American Standard thread, 6 threads per inch, this standard and size may be indicated merely by the use of a symbol or abbreviation as follows: 1½-6 NC. This is an American Standard symbol. The diameter is given first, then the number of threads per inch. The letters "NC" represent National Coarse-thread Series. The American Standard also includes a Fine-thread Series, and for this symbol would be changed as follows: 1½-12 NF. In this case, the "NF" means the National Fine-thread Series. The American Standard also includes tolerances and allowances for four different classes of fits designated by numbers. The symbol 1½-6 NC-2 means that the screw thread is to have a Class 2 fit, the fit number following the symbol indicating the diameter and number of threads per inch.

Advantages of American Standard Form: The American Standard form has largely replaced the sharp V-thread, because of its superiority. As the American Standard has a flat top (see illustration), it is not so easily injured as a sharp V-thread, and taps and dies wear less at the points of the teeth and retain their size longer. Screws having American Standard threads are from one-eighth to one-fourth stronger to resist tension than screws with V-threads, because, for a given outside diameter, there is a larger root diameter or effective area. For instance, an American Standard screw thread of 1 inch outside diameter and eight threads per inch has a root diameter of 0.8376 inch, whereas a screw of corresponding outside diameter and pitch, but with a sharp V-thread, has a root diameter of 0.7835 inch. The relative strength varies according to the size of the screw, the smaller American Standard screws being approximately one-fourth stronger than those having V-threads, whereas the larger sizes are only about one-eighth stronger in tension.



American Standard Thread

The sides of the American Standard thread form an angle of 60 degrees with each other in the plane of the axis of the screw. The width of the flat at the top and bottom equals one-eighth

of the pitch. If $p =$ pitch of thread, $d =$ depth of thread, and $f =$ width of flat at top and bottom of thread, then:

$$p = \frac{1}{\text{number of threads per inch}}$$

$$d = \tfrac{3}{4} \times p \times \cos 30 \text{ deg.} = 0.649519\, p = \frac{0.649519}{\text{No. of threads per inch}}$$

8 $\qquad$ 8 × number of threads per inch

American Standard Taper Pipe Thread. The American standard taper pipe thread is the same as the American Briggs standard. The form of the thread is a 60-degree vee, truncated equally top and bottom by an amount equal to 0.033 times the pitch of the thread. The taper of the thread, on the diameter, is 1/16 inch per inch or ¾ inch per foot. As far as the thread on the product is concerned, no change has been made from the former American Briggs standard; but to allow for a reasonable amount of wear on the taps and dies, thus making for more economical production, a modification has been made on the gages. This consists of reducing the crest of the thread gage by truncating it an amount equal to 0.10 times the pitch from the theoretical sharp point. If an old gage is correct in all other respects, it can easily be made to conform to the present standards by grinding off the excess metal at the crests of the threads. This taper thread can be used for threaded joints for any service.

American Steel and Wire Co.'s Gage. The Bureau of Standards at Washington recommends that this be referred to as Steel Wire Gage, which see.

American Wire Gage. This gage is used for bare and insulated wire of aluminum and copper; for all bare wire made of brass, phosphor-bronze, German silver, or zinc; for resistance wire of German silver or other alloys; for rods of brass, copper, and aluminum; for sheets of brass, phosphor-bronze, aluminum, and German silver. The American Wire Gage is also known as the Brown & Sharpe.

Ammeter. An ammeter or ampere-meter is an instrument for measuring the rate of flow of electric current in amperes. Several different forms of this device have been constructed, the fundamental types of which are the Weston meter, the Thomson meter, the electrodynamic meter and the electrothermic meter.

In the *Weston meter* a stationary permanent magnet acts upon a movable wire coil which is shunted by a low resistance. This meter is used for direct current only.

The *Thomson meter* consists of a small movable piece of soft iron which is acted upon by an inclined stationary wire coil through which the current to be measured passes.

The *electrodynamic meter* consists of a movable and a stationary wire coil acting magnetically upon one another. The coils are connected in series, the movable coil carrying the indicating needle.

There are two types of *electrothermic meters*, the hot-wire type and the thermocouple type. In the hot-wire meter, the current passes through a straight wire, and the amperage is measured by the expansion of the wire caused by the heating effect of the current. The expansion is transmitted by a lever to an indicating needle. The thermocouple type of meter has largely superseded the hot-wire type due to lower power loss and much greater sensitivity. In this type, suitable for use in measuring alternating currents of all frequencies, a series of junctions of two different metals is used which, when heated by the current being measured, produce a direct current to actuate a direct current measuring mechanism.

Suitable scales are provided in all types so that the current values may be read off directly in amperes, milliamperes or micro-amperes.

Amortisseur Winding. In electrical machinery, an amortisseur winding is used for making synchronous motors self-starting and for preventing hunting of synchronous generators, caused by an irregularity in the operation of the prime mover. The winding is generally of the squirrel-cage type and consists of metal rings or ring sections into which are welded or riveted bars of copper, bronze, or some other alloy of different resistance. The bars are imbedded in the pole faces of the machine, as near to the surface as practicable and parallel to the armature slots, and are usually arranged in individually short-circuited groups with bolted or otherwise separable connections between groups. This constitutes a permanently short-circuited winding so arranged as to oppose rotation or pulsation of the magnetic field with respect to the pole shoes.

Ampere. The unit of the rate of flow of an electric current, known as the *ampere,* is one-tenth of the unit of current in the centimeter-gram-second system of electro-magnetic units. It is the practical equivalent of a current which, when passed through a solution of nitrate of silver in water, deposits silver at the rate of 0.001118 gram per second. The current of an ampere will be produced by an electromotive force of one volt applied to a conductor, the resistance of which is one ohm. An ampere is also equal to the flow of a quantity of electricity of one

coulomb per second. The current in amperes is measured by *ampere-meters,* also known as *ammeters.*

Ampere-Hour. The quantity of electricity corresponding to one ampere flowing for one hour; it is equal to 3600 coulombs.

Ampere-Hour Meters. Ampere-hour meters are of two general types, the *electrolytic* and the *motor-types.* Their use is now confined practically to direct-current circuits, chiefly in connection with storage batteries or other electrolytic applications. Abroad, they have been used to some extent in the place of watt-hour meters, by assuming a fixed supply voltage. Ampere-hour meters of the electrolytic type operate on the principle of the *voltameter,* the weight or volume of the products of chemical decomposition being proportional to the ampere-hours. Motor-type ampere-hour meters are of the *commutator* and the *mercury-motor types.* In the former, a permanent magnet furnishes the field in which rotates an armature carrying a small current diverted from a shunt in the main circuit. In mercury ampere-hour meters, a rotor (usually a copper disk but sometimes a cup), is submerged in mercury contained in a chamber. Current terminals are so introduced into the chamber that the current is led through the rotor, entering and leaving by way of the mercury which serves as a contact maker. The rotor is placed in the field of a permanent magnet, rotation resulting from the interaction of the current in the rotor with the magnetic field. By the use of shunts, the meter is adapted to measure larger currents than can be handled directly.

Ampere-Second. The quantity of electricity corresponding to one ampere flowing for one second. It is equal to one *coulomb.*

Ampere-Turn. The unit of magnetomotive force. The number of ampere-turns of a circuit equals the product of the number of amperes flowing in the circuit multiplied by the number of turns, usually in the form of a coil or coils, in the circuit.

Analysis, Magnetic-Mechanical. See Magnetic-mechanical Analysis.

Analytical Chemistry. That part of chemistry which deals with the methods for determining the components of a substance. Analytical chemistry determines not only the kinds of elements that may be present in a substance, but also the amount of each.

Analytical Geometry. That part of the science of mathematics in which the location of points, lines, and surfaces is expressed by means of equations, and in which the geometrical properties can therefore be investigated by means of algebraic operations, or algebraic expression be shown graphically by means

of points or lines. In analytical geometry, the location of a point is given by stating its distance from two lines or axes which intersect each other in the case of plane analytical geometry, and from three axes intersecting at one point in the case of analytical geometry in three dimensions.

Anemometer. The anemometer is an instrument for measuring the velocity or pressure of the wind, and may also be used for measuring the velocity of air in pipes of large diameter. Experiments have shown, however, that anemometers are not reliable for the measurement of velocities of air in pipes, especially when the diameters do not exceed 24 inches, the instrument generally giving too low results when used in this manner. It has also been found that the percentage of error is not constant, but varies considerably with the diameter of the pipe and the speed of the air. Anemometers are divided into two main classes, those that measure the velocity and those that measure the pressure of the air or wind. There is, however, a close relationship between the pressure and the velocity, so that an instrument of either class can easily be made to give direct readings for both of these quantities.

Angle. When two lines intersect, an angle is formed between them. The point where the two lines intersect is called the *vertex* of the angle. Angles are measured in degrees, minutes, and seconds (1 degree = 60 minutes; 1 minute = 60 seconds). A 90-degree angle is known as a *right* angle. Angles larger than 90 degrees are called *obtuse* angles, and those less than 90 degrees, *acute* angles. The two lines forming an angle are called the *sides* of an angle. The sides of a 90-degree angle are *perpendicular* to each other.

Angle Diameter. The pitch diameter of a screw thread is sometimes called the "angle diameter," because it is measured in the angle of the thread either by using a special type of micrometer or by means of the well-known three-wire method. The pitch or angle diameter is the diameter measured halfway between the theoretical top and bottom of a screw thread, and, therefore, equals the theoretical outside diameter minus the thread depth. The term "pitch diameter" is recommended. The pitch diameter of a straight screw thread is the diameter of an imaginary cylinder the surface of which would pass through the threads at such points as to make equal the width of the threads and the width of the spaces cut by the surface of the cylinder.

Angle of Advance. The angle of advance, or "angular advance," as it is sometimes called, is generally considered the angle through which the eccentric of a steam engine must be

turned to move the valve from its mid-position to the position which it occupies at the beginning of the piston stroke. This movement of the valve on its seat equals the outside lap plus the lead; hence, the angle of advance equals the angle due to the outside lap plus the angle due to the lead. The total angle between the crank and eccentric is sometimes referred to as the angle of advance. The definition first given, however, is generally considered correct, and is more convenient to use in connection with valve diagrams and the study of valve motions, in general.

Angle of Repose. If a body is placed on an inclined plane, the friction between the body and the plane will prevent it from sliding down the inclined surface, provided the angle of the plane with the horizontal is not too great. There will be a certain angle, however, at which the body will just barely be able to remain stationary, the frictional resistance being very nearly overcome by the tendency of the body to slide down. This angle is termed the *angle of repose* and the tangent of this angle equals the coefficient of friction. The angle of repose is frequently denoted by the Greek letter. θ. Thus, $\mu = \tan\theta$. A greater force is required to start a body from a state of rest than to merely keep it in motion, because the *friction of rest* is greater than the *friction of motion.*

Angle Plate. A cast iron or forged piece having two surfaces at an angle to each other, usually a right angle, and used for holding work to be machined. One face is clamped to the machine face-plate or table and the work is supported by the other face.

Angles, Functions. See Functions of Angles.

Angle Shears. What are known as *angle shears* are designed especially for cutting angle iron and similar shapes. A common form of machine has two cutter-slides which move downward at an angle of 45 degrees with the work table.

Angle, Structural. This is one of the common standard structural sections. See Structural Shapes.

Angular Velocity. The angular velocity of a rotating body is expressed in angular measure and equals the angle through which any radius of the body turns in one second. This angle is generally expressed in radians.

$$\text{One radian} = \frac{180}{\pi} = \frac{180}{3.1416} = 57.3 \text{ degrees.}$$

The angular velocity in radians is generally denoted by the Greek letter ω. If r = radius of revolving body in feet; n =

number of revolutions per minute; and v = velocity of a point on the periphery, in feet per second; then,

$$60 \qquad \frac{v}{r} = \frac{2\pi n}{60}; \quad v =$$

Anhydrid. An oxide which unites with water to form an acid. Generally these oxides are non-metallic, although sometimes metallic oxides are anhydrid.

Animal Glue. See Glues for Wood.

Annealing. Annealing involves reheating and cooling of metals which are in the solid state. Annealing usually implies relatively slow cooling as compared, for example, with normalizing, and the purpose of annealing may be either (1) to remove stresses, (2) to soften a metal as for machining, (3) to change the ductility, toughness, electrical, magnetic or other physical properties; or (4) to refine the crystalline structure. The annealing temperature and rate of cooling depend upon the material and purpose of the treatment.

A common method of annealing steel is to pack it in a cast-iron box containing some material, such as powdered charcoal, charred bone, charred leather, slacked lime, sand, fireclay, etc. The box and its contents are then heated in a furnace to the proper temperature, for a length of time depending upon the size of the steel. After heating, the box and its contents should be allowed to cool at a rate slow enough to prevent any hardening. It is essential, when annealing, to exclude the air as completely as possible while the steel is hot, to prevent the outside of the steel from becoming oxidized.

The temperature required for annealing should be slightly above the critical point, which varies for different steels. Low-carbon steel should be annealed at about 1650 degrees F., and high-carbon steel at between 1400 and 1500 degrees F. This temperature should be maintained just long enough to heat the entire piece evenly throughout. Care should be taken not to heat the steel much above the decalescence or hardening point. When steel is heated above this temperature, the grain assumes a definite size for that particular temperature, the coarseness increasing with an increase of temperature. Moreover, if steel that has been heated above the critical point is cooled slowly, the coarseness of the grain corresponds to the coarseness at the maximum temperature; hence, the grain of annealed steel is coarser, the higher the temperature to which it is heated above the critical point. If only a small piece of steel or a single tool is to be annealed, this can be done by building up a firebrick box in an ordinary blacksmith's fire, placing the tool in it, covering

over the top, then heating the whole, covering with coke and leaving it to cool over night. Another method is to heat the steel to a red heat, bury it in dry sand, sawdust, lime, or hot ashes, and allow it to cool.

Annealing Aluminum. See Aluminum Annealing.

Annealing Chains. See Chain Annealing.

Annealing High-Speed Steel. Experiments to determine the temperature to which high-speed steel should be heated for annealing, indicated that when this steel was heated to below 1250 degrees F. and slowly cooled, as in annealing, it retained the original hardness and brittleness imparted to the steel in forging. When heated to between 1250 and 1450 degrees F., the Brinell test indicated that the steel was soft, but impact tests proved that the steel still retained its original brittleness. However, when heated to between 1475 and 1525 degrees F., the steel became very soft, it had a beautiful fine-grained fracture, and all of the initial brittleness had entirely disappeared. In carrying these tests further, to 1600, 1750, and 1850 degrees F., it was found that the steel became very soft, but there was a gradual increase in brittleness and in the size of the grain, until at 1850 degrees F. the steel became again as brittle as unannealed steel; the fracture at this temperature was dull, dry, and lifeless, and showed marked decarbonization. Dried air-slacked lime was used as a packing medium in making these tests. The steel was packed in tubes both ends of which were afterward provided with air-tight caps. The decarbonization that took place was probably due to the oxygen in the air that had filled the intervening spaces between each minute particle of lime, before it was packed in the tube, attacking the carbon of the steel; this decarbonization would not have taken place if powdered charcoal had been used. The latter would have supplied all the carbon necessary to combine with any oxygen present in the tubes.

Annealing Malleable Iron Castings. Annealing of malleable iron castings is heat-treatment designed to produce tough and ductile malleable iron from hard castings. This change is brought about by changing the pearlite and cementite of the iron to ferrite and temper carbon, which is done by heating the castings up to the temperature at which the cementite breaks down into iron and carbon. For furnace malleable castings, the temperature is maintained from 1450 degrees F. to a maximum temperature of 1600 and in some cases 1650 degrees F.

Malleable iron usually has a white outer band, approximately 1/64 inch thick, followed by a dark gray band and a velvety black interior. As the annealing proceeds, the steel band around the casting becomes thicker and the gray band thinner.

Annealing, Water Method. Quick annealing can be partially effected by what is known as "water annealing." The steel is slowly heated to a cherry red, and is then removed from the furnace. A piece of soft wood is used to test the heat of the piece of steel as it is decreasing, the heat being tested by touching the steel with the end of the stick. When the piece of steel has cooled so that the wood ceases to char, the steel is plunged quickly into soapy water. Very ofter a piece of steel annealed in this manner will be found to be much softer than if annealed in the regular way by being packed in charcoal and allowed to cool over night.

Anode. The electrodes by means of which current enters and leaves any conductor of the non-metallic class, such as an electrolyte, are known as *anode* and *cathode*, respectively. An anode is an electrode through which current enters any conductor of the non-metallic class. Specifically an electrolytic anode is an electrode at which negative ions are electrically discharged, or positive ions are formed, or at which other oxidizing reactions occur.

According to the convention that an electric current travels from positive to negative polarity, it follows that the anode of an electroplating bath is connected to the positive terminal of the current generating source, and the cathode to the negative terminal. See also cathode.

In an electronic tube, the *anode* is the element to which the electronic stream flows.

Anthracite Coal. The different kinds of coal all contain carbon, hydrogen, oxygen, and nitrogen, forming a carbonaceous or combustible portion, and also some matter which remains after the combustion in the form of ash. The amount of ash varies considerably in different kinds of coal. *Anthracite* coal contains over 90 and sometimes up to 97 per cent of carbon and has a heating value per pound of combustible of from 14,500 to 15,000 B.T.U. Anthracite is slow to ignite, and burns slowly. It is classified, according to the sizes of the pieces or lumps of the coal as obtained from the mine, into ten different kinds, ranging from "lump" to "culm." The various kinds are as follows: Lump coal, which does not pass through bars set from 3½ to 5 inches apart; steamboat coal, which does not pass through 3½-inch mesh; broken coal, which does not pass through 2¾-inch mesh, but passes 3½-inch mesh; egg coal, which does not pass 2-inch mesh, but passes 2¾-inch mesh; stove coal, which does not pass 1⅜-inch mesh, but passes 2-inch mesh; chestnut coal, which does not pass ¾-inch mesh, but passes 1⅜-inch mesh; pea coal, which does not pass ½-inch mesh, but passes ¾-inch mesh; buckwheat, which does not pass through ⅜-inch mesh, but passes ½-inch mesh; rice coal, which does not pass 3/16-inch mesh, but passes

⅜-inch mesh; culm or slack of screenings, which passes through 3/16-inch mesh. For power plants, pea, buckwheat, rice, and culm coal are generally used, the price of these sizes being considerably less than that of the larger sizes. *Semi-anthracite* coal is similar to anthracite. It contains from 85 to 90 per cent of carbon and has a heating value, per pound of combustible, of from 14,500 to 15,500 B.T.U. It is not as hard as regular anthracite, is less shiny, and burns more rapidly.

Anti-Fatigue Steel. This term is sometimes applied to vanadium steel because of its unusual resistance to continued shocks and vibrating stresses. (See Vanadium Steel.)

Anti-Freezing Mixtures. Anti-freezing mixtures for use in the radiators of gasoline engines are used to lower the freezing point below the lowest atmospheric temperature liable to occur during cold-weather operation. Alcohol and water mixtures have been widely used. Either denatured or wood alcohol may be used. The following figures represent percentages by volume of alcohol in the water and the corresponding freezing temperatures.

Denatured Alcohol: 20 per cent added to cooling water—freezing temperature, +19 degrees F.; 30 per cent, +10 degrees F.; 40 per cent, —2 degrees F. below zero; 50 per cent, —18 degrees F. below zero.

Wood Alcohol: 20 per cent added to cooling water—freezing temperature, +10 degrees F.; 30 per cent, —2 degrees F. below zero; 40 per cent, —20 degrees F. below zero; 50 per cent, —40 degrees F. below zero.

Wood alcohol should not be used unless it is definitely known to be free from acetic acid. Owing to the fact that alcohol evaporates much faster than water, the specific gravity of the mixture should be tested occasionally with a hydrometer calibrated for temperature correction. Alcohol lowers the boiling point of water, so that abnormal evaporation may occur, especially on a warm day.

Glycerine Mixtures: Glycerine raises the boiling point of water and does not evaporate like alcohol, but it is said to be somewhat more injurious to any rubber connections used between the radiator and engine. The freezing temperatures of distilled glycerine and water mixtures are as follows: 20 per cent glycerine (by volume) added to cooling water—freezing temperature, +21 degrees F.; 30 per cent, +12 degrees F.; 40 per cent, zero; 50 per cent, —15 degrees F. below zero.

Ethylene Glycol: Ethylene glycol, like glycerine, does not evaporate so that the only replacement necessary is to compensate for leaks or mechanical losses. The freezing temperatures are as follows: 20 per cent ethylene glycol (by volume) added to cool-

ing water—freezing temperature, +16 degrees F.; 30 per cent, +3 degrees F.; 40 per cent, —11 degrees F. below zero; 50 per cent, —31 degrees F. below zero.

Saline Solutions: Non-volatile anti-freezing mixtures may be made by dissolving either calcium chloride or magnesium chloride in water. These solutions are less expensive than the alcohol and glycerine solutions, but they are considered inferior due to their tendency to attack metallic parts of the system, especially if there is any solder or aluminum. Two pounds of calcium chloride to 1 gallon of water may be used for temperatures down to 18 degrees F.; 3 pounds per gallon for temperatures down to 1 degree F.; 4 pounds for temperatures down to 17 degrees F. below zero; 5 pounds for temperatures down to 39 degrees F. below zero.

Anti-Friction Curve. Same as Tractrix.

Antimony. Antimony is a silver-white, crystalline, brittle metal of high luster; it is generally found in the mineral *stibnite*, from which it is obtained by first melting this mineral to free it from various foreign matter, and then roasting it to convert it into an oxide. After oxidation, this product is reduced by heating with carbon, metallic antimony thus being obtained. During this heating, loss through volatilization must be prevented by covering the heated mass with a protective layer of potash, soda, or glauber salt. Antimony is permanent in the air at ordinary temperatures but combines with oxygen when heated to a sufficient heat. It readily combines with many other metals, forming alloys that are used to a great extent in the industries. One of the most well-known of these is *type metal*, which is an alloy of lead, antimony, and tin, sometimes containing small percentages of copper and zinc. Antimony in alloys tends to give them hardness, and the property of expanding on solidification. This property is valuable in type casting, because it produces a letter that completely fills the molds.

The atomic weight of antimony is given by two investigators as 120 and 121, and is generally assumed to be 120.2; melting point, 630 degrees C. (1166 degrees F.); boiling point, 1440 degrees C. (2625 degrees F.), but the metal begins to vaporize at about 1300 degrees C. (about 2370 degrees F.); its specific gravity is generally given as 6.71, although it may vary from 6.70 to 6.86; assuming the specific gravity to be 6.71, the weight per cubic inch is 0.2422 and the weight per cubic foot, 418.7 pounds; specific heat, 0.0523; linear expansion per unit length per degree F., 0.00000627; electric conductivity (assuming that of silver to be 100), 3.59.

Antique Bronze Finish. See Bronzing.

Anvil Quality and Weight. The quality of an anvil can generally be judged by its ring, a good anvil giving out a clear, sharp sound when struck with a hammer. If soft or defective, the sound will be dull. A good anvil so mounted that it gives out a full volume of sound is easier to work upon than one having a dead ring. Anvils ordinarily vary in weight from 150 to 300 pounds. A mistake is often made in selecting anvils that are too light for the service required. A 300-pound anvil is suitable for almost any kind of machine blacksmithing, and, if of this weight or heavier, it will not move around while in use or need to be strapped to its block. The square hole in the face of an anvil for receiving the cutting and forming tools is called the "hardie hole," and the small round hole near it, the "pritchel hole." Many anvils have a wrought-iron body to which is welded a hardened steel face. If an anvil is made from cast or wrought iron, the horn should be of steel, in addition to the top being steel-faced. A blacksmith's anvil should be set in relation to the forge so that the horn will be at the blacksmith's left when he turns around to forge a piece. But if he is a left-handed blacksmith, the horn should be on his right hand.

Aperiodic. This term is sometimes applied to an electrical or other measuring instrument which is said to be "dead beat" or which has an indicating hand that moves to position without excessive oscillations. See Damping.

Apothecaries' Fluid Measure. 1 U. S. fluid ounce = 8 drachms = 1.805 cubic inches = 1/128 U. S. gallon; 1 fluid drachm = 60 minims; 1 British fluid ounce = 1.732 cubic inches.

Apothecaries' Weight. 1 pound = 12 ounces = 5760 grains; 1 ounce = 8 drachms = 480 grains; 1 drachm = 3 scruples = 60 grains; 1 scruple = 20 grains.

Apparent Power. The expression "apparent power" is used in connection with alternating-current circuits, to distinguish it from the true power or energy. It is the product of the mean effective value of the voltage across the circuit multiplied by the mean effective value of the current therein, as read directly from a voltmeter and ammeter. It is expressed in kilovolt-amperes (kva).

$$\text{Apparent power} = \frac{\text{true power}}{\text{power factor}}.$$

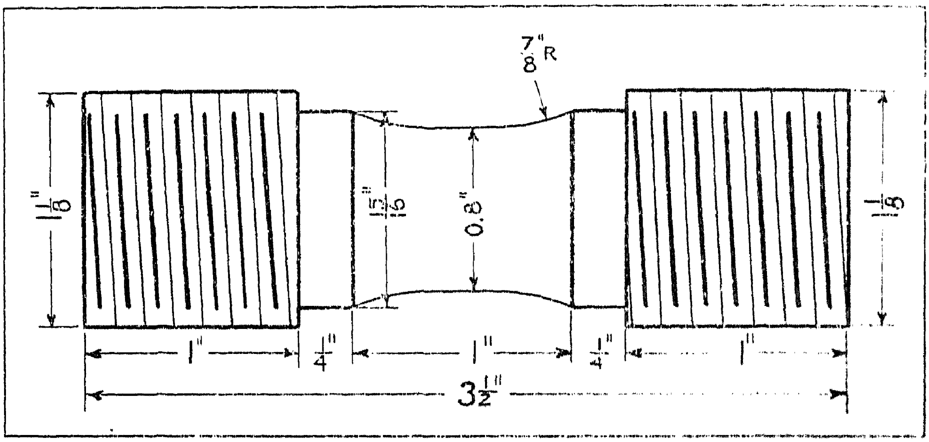
For unity power factor, the apparent power in volt-amperes is equal to the true power, expressed in watts.

Apprentice Training Plan, Milwaukee. See Milwaukee Apprentice Training Plan.

Apron. In machine construction, a protecting cover which en closes a mechanism is sometimes called an apron, this term being applied particularly to the apron of a lathe which covers the mechanism employed for transmitting feed motion to the cross-slide and for engaging and disengaging the feed motion of either the cross-slide or the carriage.

Aqua-Fortis. A term applied especially to a weak grade of nitric acid.

Aqua Regia. Aqua regia is a mixture composed of three parts of hydrochloric (muriatic) acid and one part of nitric acid; it has a reddish yellow color, and has the peculiar quality of dissolving gold, platinum, and other rare metals which are insoluble in other acids. It is often used as an etching fluid, especially for



Standard Bar for Testing Tensile Strength of Cast Iron

high-speed steel. It should be used immediately after being prepared or mixed, as it loses its properties even after a short time.

Aquometer. An aquometer, more generally known as a *pulsometer,* may be defined as a steam pump which acts partly by direct steam pressure and partly by vacuum. See Pulsometer.

Arbitration Test Bar. This is the name of a test bar for cast iron conforming to the specifications of the American Society for Testing Materials. For transverse testing, the cast test bar has a body length of 21 inches and a diameter at the center of 1.2 inches. The diameter of the bar at the bottom is 0.05 inch smaller than the top to allow for draft and for the strain of pouring. The mold is made in cores or in dry sand. In transverse testing, the bar is placed horizontally on supports 18 inches apart with a centrally applied load. The tensile strength of cast

is determined by using a tension test specimen conforming to the dimensions shown in the accompanying illustration. The ends have a standard thread $1\frac{1}{8}$ inches in diameter for gripping the test specimen in the tensile testing machine.

Arbor and Mandrel. The names *arbor* and *mandrel* are often used interchangeably to designate a shaft or spindle that is employed for holding bored parts while turning the outside surfaces in a lathe. Tools of this class are known as "mandrels" by most small-tool manufacturers, whereas the spindles or supports for milling cutters, saws, etc., are called "arbors." In a great many machine shops and tool-rooms, however, the term arbor is commonly used to indicate a tool or shaft for holding parts while turning, although some forms of work-holding devices are known as mandrels even by those who ordinarily use the name arbor. A cylindrical piece or other form about which a blacksmith sometimes forges a ring or collar is known as a mandrel, and this name is applied to other classes of tools which are never referred to as arbors.

Arbor Press. Arbor presses provide effective means of forcing arbors or mandrels into drilled or bored parts preparatory to turning or grinding operations on the exterior. In using the arbor press, the work is placed on the base with the hole in a vertical position, and the arbor (which should be oiled slightly) is forced down into it by a ram, operated either by hand or power. Power-driven arbor presses are particularly desirable for large work, owing to the greater pressure required for inserting arbors that are comparatively large in diameter. Arbor presses can also be used for other purposes, such as forcing bushings or pins into or out of holes, bending or straightening parts, or for similar work.

Arc. See Electric Arc.

Archimedean Principle. Two of the fundamental principles of mechanics are frequently spoken of as the *Archimedean principles*, because of their having been originated by Archimedes, the Greek mathematician, who lived in the third century B.C. The first of these principles relates to the equilibrium of a lever, laying down the law that equilibrium will exist when the moments of two weights on opposite sides of the fulcrum are equal. The other principle, more frequently known as the *Archimedean law*, relates to hydrostatics, and pronounces the fact that a body immersed in a fluid loses an amount of weight equal to that of the fluid it displaces.

Archimedean Screw. A device, said to have been invented by Archimedes for raising water, consists principally of a cylinder

within which is a shaft with a deep helical thread or groove. The cylinder is placed in an inclined position with its lower end and the screw immersed in water. As the tops of the thread of the screw fit the cylinder closely, water will move upward through the helical chambers formed by the groove or thread when the screw is revolved. The modern screw conveyer, used for raising other materials, is a form of Archimedean screw.

Archine. A Russian measure of length, equal to 28 inches or 0.711 meter.

Arch Power Presses. Presses of this class include designs built with a wide bed and arched frame, and a comparatively small slide. Such presses are recommended mainly for large blanking work or shallow forming operations on the lighter gages of metal.

Arcing Grounds. Grounds on transmission and cable systems are frequently the cause of interruptions and damages to apparatus. On overhead lines, the arc to ground breaks insulators and burns off the line conductors. On underground cable systems, the arc to ground quickly burns to the other conductors, causing a short circuit. In addition to these troubles, due to the heat of the arc, the rapid make-and-break of the arc sets up high frequency disturbances which are very dangerous to the system and the connected apparatus. It also causes great annoyance by interfering with the operation of parallel telephone lines.

Arc Light. The light produced by two carbon rods which are connected in an electric circuit so that the circuit is closed by the contact of the tips of the carbon rods. When, after such contact, the carbon rods are again separated, the electric circuit is not broken, if the space between the carbons is not made too great, and an arc of light will be formed between the two points. The light emitted is due to the intense heat of the tips of the carbon rods, and also, to a smaller degree, to the arc itself. It is commonly used in searchlights or spotlights or wherever a light of high intensity is required.

When *direct current* is used for arc lighting, most of the light is produced by the end of the upper or positive carbon rod, or electrode, which acquires a hollow center known as the "crater of the arc." This crater, which throws the light downward, has a temperature of from 5500 to 6000 degrees F., a temperature that is high enough to vaporize carbon. The lower or negative carbon rod or electrode becomes pointed at the same time as the positive one is hollowed out. The carbons are consumed by the passage of the current, the positive electrode being reduced in size about twice as fast as the negative electrode.

When an *alternating current* is used for arc lamps, the upper carbon becomes alternately the positive and the negative electrode and, in this case, no crater is formed; but both electrodes become pointed and the two electrodes give off about the same amount of light and are consumed with about the same rapidity. The great illuminating property of the crater in the direct-current arc, however, is lost, and the light given out by the alternating-current arc is thrown upward as much as downward, which makes it necessary to use a reflector in order to take advantage of the full effect of the light produced.

When carbons, the cores of which have been treated with metallic salts, are utilized, the resulting arc may be used as a source of ultraviolet light, as in sun lamps.

Arc-Light Rope. A wire rope known as *arc-light rope* is made from 9 strands each containing 4 or 7 galvanized wires, and a hemp center. It is used primarily for supporting arc lights, and is made in diameters varying by 16ths from ¼ to ½ inch. The ¼- and 5/16-inch sizes are constructed from strands with 4 wires each, while the larger sizes are constructed from strands having 7 wires each. The breaking strength of arc-light rope is 1125 pounds for the ¼-inch size, 2200 pounds for the ⅜-inch size, and 4700 pounds for the ½-inch size. This rope may be used to advantage for all purposes where a rope is exposed to moisture.

Arc of Action. This term, as applied to gearing, is the angular distance a tooth travels from the point where it first makes contact with its mating tooth until it leaves contact (sometimes called angle of action). *Arc of approach* is the angular distance from the point where tooth contact begins to the intersection of the point of contact with the pitch line. *Arc of recession* is the angular distance from the intersection of the point of contact with the pitch line to the point where tooth contact ceases. The arc of approach and the arc of recession depend upon the pressure angle, the outside radius, the pitch radius, and the base-circle radius.

Arc Sine and Tangent. The expressions "arc sine," "arc tangent," "arc cosine," and "arc cotangent," or, as used in their abbreviated forms, "arc sin," "arc tan," "arc cos," and "arc cot," are used to signify the arc or angle which corresponds to a given value of cosine, cotangent, etc. For example, the sine of 40 degrees is 0.6428; then, arc sin 0.6428 = 40 degrees. The expression "arc sin a" is also written "$\sin^{-1} a$." This latter method, while frequently used, is hardly mathematical in its form, because the use of a negative exponent in this manner might easily lead to confusion and be misunderstood for the expression "$(\sin a)^{-1}$," which means the reciprocal of $\sin a$, or $1 \div \sin a$.

Arc Welding. The principle involved in arc welding consists chiefly in the heating of the work to be welded to a welding heat by means of an electric arc produced or struck (1) between the part to be welded and a carbon electrode; (2) between the work itself and a metallic electrode. When carbon electrodes are used, a metal rod is nearly always employed for feeding additional material into the joint to be welded. When a metallic electrode is used, this electrode is made from a metal which itself is suitable for feeding into the joint to form the material required to complete the weld. See Electric Welding.

Arc-Welding Apparatus, Automatic. The term "automatic arc welder" has been applied to welding apparatus so designed that the wire used in metallic electrode welding is fed mechanically at whatever speed is necessary to maintain a constant arc length and arc voltage. The feeding movement is varied according to the size of the wire and the welding current used, provision being made to obtain the necessary variations. This feeding movement is derived from a small motor which drives the wire-feeding mechanism. This automatic arc welder can be used to advantage in welding long continuous seams on pipes, tanks, boilers, etc., where operation is on a production schedule, and such equipment is also being utilized on railways for building up worn cross heads, guides and wheel flanges.

Arc-Welding Methods. The various methods of electric arc welding may be described as follows:

Carbon arc welding is an arc-welding process wherein a hard carbon or a graphite electrode is used and filler metal, if required, is supplied by a welding rod.

Shielded carbon arc welding is a carbon arc-welding process wherein the molten filler and weld metals are effectively protected from the air by supplemental means.

Metal arc welding is an arc-welding process wherein the electrode used is a metal rod or wire, which, when melted by the arc, supplies the filler metal in the weld.

Shielded metal arc welding is a metal arc-welding process wherein the molten filler and weld metals are effectively protected from the air by supplemental means.

Atomic hydrogen welding is a fusion-welding process wherein the heat of an electric arc between two suitable electrodes is used to dissociate molecular hydrogen into its atomic form, which, on recombining in the molecular form, gives up the energy required to dissociate it, producing a flame of very high temperature and at the same time bathing the molten weld metal in hydrogen. It may be considered as a combination of the gas and arc-welding processes.

Argentan. The name "argentan" is sometimes used for an alloy of varying proportions of nickel, copper, and zinc. This alloy is more commonly known as German silver or nickel-silver, the name "argentan" being used only as a trade name for a certain product of this kind.

Argon. Argon is one of the gaseous chemical elements forming one of the minor constituents of atmospheric air. Its chemical symbol is A; its atomic weight, 39.9; it becomes liquid at a temperature of —186 degrees C. (—302 degrees F.), and solidifies at a temperature of —189 degrees C. (—308 degrees F.). It forms about 0.94 per cent, by volume, of the atmosphere.

Arithmetical Progression. An arithmetical progression is a series of numbers in which each consecutive term differs from the preceding one by a fixed amount called the *common difference, d.* Thus, 1, 3, 5, 7, etc., is an arithmetical progression where the difference *d* is 2. The difference in this case is *added* to the preceding term, and the progression is called *increasing.* In the series 13, 10, 7, 4, etc., the difference is (—3), and the progression is called *decreasing.*

Armature. Two essential parts of all generators and motors are the *field magnets,* which produce the necessary magnetic flux, and the *armature,* on which the conductors are arranged. The armature of a generator is that part of the machine containing the winding in which the electromotive force is generated. For direct-current machines, the armature is generally revolving, while, for alternating-current machinery, it is mostly stationary, this being preferable as it makes it easier to insulate the windings, which is important, especially in high-voltage machines. To prevent eddy-currents, armature cores are constructed of iron or soft-steel disks from 0.014 to 0.031 inch thick, arranged parallel to the lines of force and perpendicular to the axis of rotation. These disks are insulated from one another by varnish, and the slots are punched on the periphery for holding the windings.

That member of a solenoid or an electromagnetic relay which is moved by changes produced in the electromagnetic field is also called an armature. In a solenoid an armature takes the form of a plunger moving longitudinally, while in a relay it is usually a pivoted arm.

Armature, Motor. The armature of a motor may be divided into four primary parts: (1) the shaft, which transmits the turning moment to the load; (2) the "armature punchings," which are thin disks of magnetic silicon steel assembled on the shaft, insulated from each other to prevent eddy-current losses, held rigidly in the form of a cylinder, and (excepting some types

of motors) having slots cut around the periphery of this cylinder for the reception of the armature windings; (3) the armature windings composed of the current-carrying windings or bars to receive current from the source of power through the commutator or by induction, and (4) the current collecting element which may be a commutator made up of many copper segments insulated from each other but connected to the armature windings, or slip rings, which are merely continuous rings of copper also connected to the armature windings. Both commutator and slip rings serve the purpose of collecting current from the line through brushes which are in contact with them and of delivering this current to the armature windings. Direct current motors are equipped with commutators, while alternating current motors may utilize either commutators or slip rings, or both.

Where all of these parts are not present, as in squirrel cage motors, which require no current collecting element since they are run by electromagnetic induction, or as in very small synchronous motors such as are used in clocks, the rotating member of the motor is more properly called a rotor.

Armature Reaction. The useful magnetic flux in the field of a generator under load, or a motor, is produced by the resultant magnetomotive force of the field-exciting current and of the armature current. *Armature reaction* is the term used to denote the influence of the armature current in modifying the value of the field flux. It is measured in ampere-turns, since it is a magnetomotive force. When the armature current leads the induced electromotive force (emf) in the armature conductors, the armature magnetomotive force (mmf) assists the field mmf and so strengthens the field. When the armature current lags behind the induced emf, the armature mmf opposes the field mmf and so weakens the field. When the current and the induced emf are in phase, the two magnetomotive forces neither assist nor oppose each other, and the influence of the armature reaction is only to distort the main field without changing its value.

The induced armature emf is proportional to the flux per pole, and thus, with leading current in the armature, the induced emf is greater than the open-circuit voltage, and, with lagging current, less than the open-circuit voltage. In the latter case, when load is put on the machine, the field excitation must, therefore, be increased in order to overcome the armature reaction by an amount sufficient to neutralize the armature-demagnetizing magnetomotive force.

The armature reaction of a motor is in the opposite direction to that of a generator running in the same direction, and the field is consequently distorted in the opposite direction.

Armature Windings. Three main types of windings are used on armatures or rotors of electrical machines. One type consists of wire wound coils which are assembled in slotted cores around the periphery of the armature. A second type, known as a squirrel cage, consists of copper or aluminum bars fitted into slots in the rotor and connected at each end by a continuous ring. A third type, used in synchronous motors, has individually wound pole pieces fastened around the rotor core.

Two kinds of winding are employed in the first type: the multiple, parallel or lap winding, and the series, wave or chain winding. The former is used in direct current machines, alternating current motors, rotary converters, induction motors and alternating current generators. The latter is used in direct current generator armatures where a higher voltage is needed in electric railway motors and where the multiple winding is impractical.

The squirrel cage winding may be of a single or double type, the latter consisting of an outer winding or set of cross bars of high resistance and low reactance which carries the starting current, and an inner winding or set of cross bars of low resistance and high reactance which carries the running current.

Armored Cable. Underground electric cables and submarine cables are usually protected from mechanical abrasion by galvanized steel wire, known as armor wire. This is a mild steel wire of uniform diameter, having a tensile strength of about 50,000 pounds per square inch, and an elongation of not less than 10 per cent in 8 inches. Steel tape is also used for mechanical protection. Additional protection is often secured by the use of lead sheathing which excludes moisture.

Armstrong Joint. A two-bolt flanged or lugged connection between pipes for high pressures is known as an Armstrong joint. The ends of the pipe are formed so as to hold properly a *gutta-percha* ring. This form of joint was originally used for cast-iron pipe only. There are various substitutes for this class of joint, many of which employ rubber in place of gutta-percha, and, in some modifications, more than two bolts are used.

Arnold Grinding Gage. This is a size-indicating gage used on grinding machines. It has contact points tipped with tungsten carbide. These points are in contact with the part being ground. The reduction in diameter is shown by a dial gage. In some cases, a single dial gage is used and in others two gages are employed. Sometimes two gages are used when considerable stock must be removed, and roughing and finishing cuts are indicated separately. For example, the first indicator graduated to 0.001 inch may be used for the roughing cuts; then a second indicator, graduated to 0.0001 inch, begins to register for the

final finishing cut. With another arrangement, as applied to crankshaft grinders, one indicator is for pin diameter and a second for pin width. These special crankpin grinding machines are equipped with means for accurately locating the wheel opposite each pin to be ground.

Arsenic. A chemical element, steel-gray in color, having a metallic luster and being very brittle, the symbol of which is As, and the atomic weight, 75.0. The specific gravity varies from 5.4 to 5.95, and the melting point is 850 degrees C. (about 1560 degrees F.). It is a constituent of certain minerals containing iron, nickel, and cobalt, and is also found in small quantities in nearly all iron pyrites.

Asarcoloy No. 7. Bearing metal having Brinell hardness at 82 degrees F. of 33; at 390 degrees F., 7. Yield point in tension, 11,700 pounds per square inch. Elongation at 82 degrees F., 19; at 390 degrees F., 111. Compressive strength at 82 degrees F., 21,800 pounds per square inch; at 390 degrees F., 4400 pounds per square inch. Meets the demands for a bearing metal for high-speed, high-compression engines. Since the alloy bonds directly with steel, the same composition as is used for the bearing proper can be used for bonding. The nickel penetrates the steel slightly, as when welding nickel to steel.

Asbestine. A material used in paints for protecting iron and steel against corrosion, consisting of a natural silicate of magnesia. When used in paints, it prevents the settling of other pigments, and strengthens the paint film. It grinds in 32 per cent of oil. It also occurs in the form known as *talcose*.

Asbestos. Asbestos is a fibrous mineral which is noncombustible and therefore has many uses in the industries for fire protective purposes. The composition of asbestos varies somewhat according to the source from which it is obtained. Analyses made of various grades indicate that it contains about 40 per cent of silica, from 42 to 43 per cent of magnesia, from 1 to 3 per cent of ferrous oxide, from 1 to 2 per cent of alumina, and from 13 to 14 per cent of water. Asbestos was formerly a rare curiosity, but now it is applied to a great variety of uses in industrial arts, and these applications are constantly increasing. Its value in the industries depends not only upon its property of withstanding a high temperature, but also upon its low thermal conductivity, making it an excellent heat-insulating material for boilers and steam pipes. It also partially resists the action of acids, and is used as a filtering material for corrosive liquids. It is made up in a number of different forms, such as yarn, felt, paper, boards, etc., and is employed in many fireproof

cements. Asbestos is also used as an electric insulating material, but loses its insulating qualities at about 1800 degrees F., although it will recover these qualities, when cooled. Its usefulness as an electrical insulation is impaired somewhat by its hygroscopic property and the presence of iron oxide particles which are difficult to remove. It also loses its mechanical strength at the temperature mentioned, and will melt at about 2400 degrees F. As a non-conductor of heat, it has been applied to a large extent as an insulating material in electric heating devices of various types.

Ashberry Metal. Ashberry metal is a composition consisting of 77.8 per cent of tin; 19.4 per cent of antimony; and 2.8 per cent of copper. It belongs to the class of metals generally known as *Britannia metals.* An alloy of the same composition, except that zinc is substituted for the copper, is also known as ashberry metal.

Asphaltum. Asphaltum or "asphalt" may be either a natural product or the heavy residuum from petroleum. The latter are known as oil asphalts and are obtained largely from mid-continent, Texas, California and Mexican petroleums. Asphalt is a black non-oxidized bituminous hydro-carbon, ranging from semi-fluid to hard in consistency.

Asphaltum is extensively used for flooring and paving purposes, and is also employed as a preservative coating for iron and steel. It is applied either by dipping the object to be coated into a molten bath of asphaltum, as in the case of water pipe, or by pouring the asphaltum onto the surface to be protected, as in the case of bridge floors. The asphaltum to be used for the protection of iron and steel should be applied at from 300 to 400 degrees F. It should be slightly elastic, when cold, and should not soften appreciably at 100 degrees F. The surface to which it is applied should be dry and hot, and the coating should be of considerable thickness.

Asphaltum is also used in engineering as a component of waterproof cements, and also as a waterproof coating for a number of purposes. Asphalt compositions are also to some extent acid-proof, and are used as cement in pipe lines, tanks, etc., where acids or acid vapors must be resisted. Pure asphalt softens at from 200 to 210 degrees F., and is not recommended in cases where it is subjected to heat or to high stresses. As an electric insulating material, asphalt is used to a great extent, as insulation containing asphalt possesses a high resistance to puncture, in addition to flexibility and mechanical toughness. It is also cheap and is not affected by moisture. It is used for the manufacture of insulating varnishes, for the impregnation

of insulating materials in order to make them waterproof, and as an insulating covering for cables. The puncturing voltage varies from 5000 to 15,000 volts per millimeter (0.039 inch).

Assembly, Progressive. See Progressive Assembly.

Assembly, Selective. See Selective Assembly.

Atmospheric Condenser. Water is the cooling medium used in practically all steam engine condensing apparatus. Air may be used where water is difficult to get or carry or is costly, but air is much less effective than water and the surface for an equal cooling effect has to be much larger. One form of atmospheric condenser consists of an outer cylindrical shell to which are attached upper and lower tube sheets. This shell is filled with air tubes of 4-inch wrought-iron pipe, which extend about 4 inches above the upper tube sheet. The exhaust steam enters through a special form of distributor near the bottom of the shell and is made to circulate among the tubes by means of baffle plates. Extending above the condenser there is a flue 50 feet in height. The cooling effect is produced by an upward current of air through the tube which is greatly increased by pumping water into the water-pan above the upper tube sheet. This water trickles downward through the tubes and into a cistern below the condenser. The upper ends of the tubes are notched so that the water, in passing into them, spreads into thin sheets, thus covering the inside surfaces. The exhaust steam in the shell of the condenser heats the tubes and the films of water, causing the latter to evaporate rapidly, thus saturating the air and causing it to pass swiftly up the tubes, carrying with it large quantities of heat taken from the condensing steam. The water of condensation is drawn off through a drain connection in the lower tube sheet; whereas, the air is exhausted from the cylindrical drum by means of a pump connecting with an outlet located just below the upper tube sheet. The air and drain pipes are connected and extend to a vacuum or air pump.

Atmospheric Engine. In one of the early types of steam engine, known as the "atmospheric" engine, the steam was admitted only to the under side of the piston and forced the piston upward, while the down-stroke was effected by the pressure of the atmosphere, a vacuum having been formed under the piston through the condensation of the steam. The cylinder was placed in a vertical direction. This engine was invented by Papin, in 1695, and was first made a practical success by Newcomen, and, subsequently, greatly improved by Watt, who added a separate condenser and air pump.

Atmospheric Line. An atmospheric line is one drawn on an engine "work diagram," parallel to the line of absolute vacuum

and at such a distance above it as to represent 14.7 pounds pressure per square inch.

Atmospheric Pressure. The normal atmospheric pressure at sea level is generally assumed to be 14.7 pounds per square inch, which corresponds to 29.92 inches of mercury. Frequently, however, the atmospheric pressure is assumed to be the pressure of a 30-inch vertical column of mercury at 32 degrees F., which corresponds to 14.73 pounds per square inch. In the countries using the metric system, the pressure of an atmosphere equals 760 millimeters of mercury (29.92 inches) at 32 degrees F. This corresponds exactly with a pressure of 14.7 pounds per square inch, and is the value generally used in engineering calculations. The pressure in atmospheres is frequently used as a measure for air, steam, or liquid pressures. For example, a pressure of five atmospheres would equal $5 \times 14.7 = 73.5$ pounds per square inch. In calculations where extreme accuracy is not required, it is often assumed that an atmosphere equals 15 pounds per square inch. This makes it easier to perform calculations, five atmospheres being then equal to 75 pounds per square inch.

Atomic Hydrogen Welding. A fusion welding process wherein the heat of an electric arc between two suitable electrodes is used to dissociate molecular hydrogen into its atomic form, which on recombination in the molecular form gives up the energy required to dissociate it, producing a flame of very high temperature and at the same time bathing the molten metal in hydrogen. It may be considered as a combination of the gas and arc welding processes.

With atomic hydrogen welding, metals can be fused without oxidation, welding being performed in some cases on metals as thin as paper. Since atomic hydrogen is a powerful reducing agent, it reduces any oxides which might otherwise form on the surface of the metal. Alloys containing chromium, aluminum, silicon, or manganese can be welded without fluxes and without surface oxidation.

Atomic Weights. Atoms are too small to have their absolute weights determined; therefore, hydrogen, being the lightest known element, was first taken as a unit, and the atomic weights of all other elements were compared with this. It was supposed that, when the atomic weight of hydrogen was taken as the unit, the atomic weight of oxygen was 16, so that atomic weights, expressed on the basis of the hydrogen atomic weight being equal to 1, would also compare directly with the atomic weight of oxygen, expressed as 16. Later investigations have shown, however, that this ratio between the atomic weights of

oxygen and hydrogen is 15.88 to 1. The leading chemical societies of the world, however, decided to retain the value of the atomic weight of oxygen as 16, and the atomic weights based on this standard are known as "international atomic weights." It has been found that the specific heat of an element multiplied by its atomic weight is a constant closely approximating the value 6.25. Upon this fact a method of determining atomic weight has been based, as the atomic weight may be found approximately by dividing 6.25 by the specific heat.

Audio Frequency. An audio frequency is a frequency corresponding to a normally audible sound wave. Audio frequencies range roughly from 20 to 15,000 cycles per second.

Auger Speeds. Auger speeds depend largely upon the condition of the wood in regard to seasoning. For example, with the same wood, say pine, speeds could vary by as much as one-third for samples that were very resinous or not properly seasoned. A hard wood, say mahogany, can be satisfactorily cut at a heavier feed and quicker speed than a soft wood badly seasoned or spongy. With spongy woods, there is often difficulty in clearing the chip or core, and this limits the speed. Again, many woodworking machines have an insufficient range of speeds, and small augers have to be underspeeded to avoid overspeeding the large ones. The following speeds for average woods may be taken as a guide for use with a good quality machine and auger: ½-inch augers, 200 revolutions per minute; ¾-inch augers, 1600; 1-inch augers, 1300; 1¼-inch augers, 1200; 1½-inch, 1100; and 2-inch, 1000.

Austenite. Austenite is the solid solution of iron carbide in steel heated above a temperature of about 1300 degrees F. (about 700 degrees C.). Normally, when the metal cools below this point, austenite divides into *ferrite* and *cementite*, the former being practically pure iron and the later being iron carbide. The dissolution may be avoided partly by suddenly cooling the steel in water, and completely by adding manganese, nickel, tungsten, or molybdenum. Some of the manganese and nickel steels are manganiferous and niccoliferous austenite. Austenite is non-magnetic; hence, steel heated to the hardening temperature is non-magnetic. Austenite is very malleable, and, at the same time, very hard. As the sudden quenching of iron, as when hardening high-carbon steel, only partly preserves the austenite, carbon steel is strongly magnetic.

Autogenous Welding. The process of fusing and uniting metals by the application of intense heat from a gas flame without compression or hammering is generally known as "autoge-

nous welding." The temperature required is obtained by the combustion of a gas containing carbon or hydrogen, or both, by the aid of oxygen. Acetylene is the gas generally used with oxygen although hydrogen is also employed. The gases are thoroughly mixed in a torch or blowpipe to insure perfect combustion, which takes place at the nozzle or tip. Strictly speaking, electric welding is also a form of autogenous welding, but in practice the term has become limited to the form of welding accomplished by means of the blowpipe. Ordinarily, the weld is formed by fusing-in additional material between the surfaces of the joint, which material is in the form of a rod or wire, and may or may not be of the same composition as the material being welded. The heat of the welding torch is also utilized for the cutting of metals by melting and burning the metal away. The autogenous welding process is used both in the manufacture of articles, the parts of which would otherwise be riveted or joined by other means, and in repair work. In both fields it has proved to be of exceptional value.

Automatic. The term "automatic" is often used as a noun in the machine-building industry, to indicate any kind of automatic turning machine, especially an automatic screw machine or automatic chucking and turning machine of the turret lathe class. See Automatic Machine Tool Classification.

Automatic Dies. See Dies for Thread-cutting.

Automatic Engines. Many stationary engines are equipped with valves that are controlled by governors of the shaft or flywheel type, the arrangement being such that a practically uniform speed of the engine is maintained automatically by the direct action of the governor upon the valve. For instance, if the engine speed varies, the position of the governor eccentric is changed, which, in turn, causes a change in the position of the valve, thus altering the point of cut-off and either reducing or increasing the speed, depending upon whether it is above or below the normal speed. Engines of this general type are often called "automatic" engines. There are various types of governors for engines of this class, and the valves also vary considerably, some engines having a single slide valve controlled by a shaft governor, whereas others have a main valve provided with an auxiliary "riding" or cut-off valve, which is controlled by the governor. The change in the position of the governor eccentric for varying the valve travel and point of cut-off is effected in different ways. The eccentric may be shifted by changing the angle between it and the crank, or the eccentricity alone may be changed, or both the angularity and eccentricity may be changed simultaneously. The first two methods are

rarely employed with a single valve; in fact, most fly-wheel governors are so arranged that, when the engine speed increases, the angle between the crank and the eccentric, as well as the eccentricity, is changed at the same time.

Automatic Gear-Cutting Machines. Machines of the formed-cutter types are commonly known as "automatic" gear-cutting machines because, after the gear blank or blanks are in the cutting position and the machine is properly adjusted, all the gear teeth are cut automatically without further attention on the part of the operator. There are certain other types of gear-cutting machines which also operate automatically, except for the insertion and removal of the work, but the term "automatic" is not used in designating them to the extent that it is applied to spur-gear machines of the formed-cutter type.

The general characteristics of these automatic spur-gear machines include a main spindle for holding and driving the work-holding arbor; a cutter-slide arranged to move parallel with the axis of the work-spindle; a mechanism for feeding the cutter-slide at a suitable rate and returning it to the starting point; and a mechanism for indexing the gear blank after each tooth space is milled.

Automatic Lathe. The automatic lathe is so designed that all of the tool movements are automatically controlled, although the work must be inserted and removed by an attendant. The original machine in this field is the Fay automatic lathe. This type of machine has a headstock and tailstock for driving and supporting the work, the same as on a standard engine lathe, and, in addition, it is equipped with a carriage and supplementary facing and forming tools that are operated automatically. This machine is used for turning rough forgings which may be held on centers, but its principal use is for work held on an arbor; therefore, it is primarily a second-operation machine, completing work that has previously been chucked and otherwise partly finished on the drill press or turrent lathe.

Automatic Machine Tool Classification. The term "automatic," as applied to various classes of machine tools, does not always have the same meaning, and a machine which one manufacturer classifies as automatic would be considered semi-automatic by another manufacturer. For instance, some machines which are designed to perform a certain cycle of operations, but are not capable of presenting unfinished parts to the tools, may be referred to as automatic machines. While such a machine is automatic or self-moving in that it controls the movements of the cutting tools through one cycle of operations, the attention

of an operator is required, so that such a machine is really only semi-automatic.

There are other types of machines which not only control all the movements of the cutting tools, but are equipped with work-feeding mechanisms so that, when one part has been finished, other duplicate parts may be produced automatically. The operation of such a machine is continuous until it needs to be supplied with raw material, which may either be in the form of bar stock, or separate castings or forgings, when a magazine feeding attachment is used. A machine of this type is automatic in the sense that it repeatedly performs all of the necessary operations, which include ejecting the finished work and presenting a new piece or length of stock to the tool. Thus when a machine is capable of automatically producing duplicate parts repeatedly, it is universally referred to as automatic, whereas, if it simply performs a complete cycle of machining operations, but requires the attention of an operator each time a part is finished, it may be considered automatic by some, and semi-automatic by others. In some cases, a machine of the latter class is termed "automatic," while one that is capable of continuous operation is known as a "fully automatic."

Automatic Screw Machine. The original field of the automatic screw machine was, as its name implies, the making of screws. This field was quickly enlarged to include the making of all kinds of small nuts, washers, pins, collars, etc., and, at the present time, machines of this class are capable of a great variety of operations, not only on parts which are turned from bar stock, but on separate castings or forgings that are automatically fed to the machine by a special feeding mechanism.

Characteristic features of screw machines in general are means for automatically locating successive tools in the correct working position, the automatic changing of feeds and speeds to secure economical operation, and the presenting of new stock to the tools for a similar series of operations. These various movements, which are entirely automatic, are obtained principally from cams which are rotated at pre-determined speeds, and are so formed and set relative to one another that the parts of the machine which they control all operate at the proper time, and at suitable speeds. There are two general classes of screw machines, one class having a single work-spindle and the other, several work-spindles—usually four, five or six spindles. Each spindle of the multiple-spindle type holds a bar stock, and tool-holders feed tools forward to operate on these bars of stock held in the opposing work-spindles. After a tool-holder has concluded its working stroke and returned to the starting position, the work-spindle carrier or head is revolved, bringing each

bar of stock to the next tool in rotation. The final tool position provides for a cut-off blade, and a complete piece is finished and cut off at each indexing. One or more forming slides also operate at the different spindle positions if necessary. With this type of machine, all the cutting tools are working on each feeding stroke, as each has a bar of stock presented to it, whereas, with a single-spindle machine, the various tools of the turret operate successively on a single bar of stock.

The time required to complete a part on a single-spindle machine is equal to the total time necessary for all of the individual operations, which includes the time for withdrawing the tools at the completion of the cut, indexing the turret and presenting the succeeding tools to the work. With a multiple-spindle machine, the total time required to complete a piece is equal to the time necessary for the longest single operation plus the time for the idle movements; in some cases, the time is reduced by dividing the longest operation into two operations.

Automatic Screw Machine Origin. A great field was opened in machine tool development by the invention of the "automatic turret lathe" by Christopher N. Spencer, who was then connected with the Billings & Spencer Co. The idea of designing an automatic turret lathe or screw machine was suggested to Spencer by another machine which he had invented for turning spools for sewing machines. The action of this automatic turret lathe was controlled by a cam cylinder provided with flat strips adjustable according to the movements required, but this exceedingly important feature was overlooked by the patent attorney. This machine proved so successful for making screws automatically that Spencer severed active relations with Billings & Spencer Co. in 1874 and soon afterward established, with others, the Hartford Machine Screw Co.

Automatic Stop and Check-Valves. The general practice in steam power plant design is to use two valves in each steam lead from the boilers—the steam pipe which connects the boiler with the main header. One of these valves should be placed at the steam outlet of the boiler and the other at the main header. The valve placed next to the boiler nozzle should be an "automatic stop and check-valve," so called because it closes automatically when the pressure in the boiler falls below the pressure in the steam main, and opens automatically when the pressure in the boiler exceeds the pressure in the steam main. Automatic stop and check-valves are coming into general use, and, where two or more boilers feed into a common main or header, they are required by law in some countries.

With several boilers feeding into the same main and not prop-

erly protected by automatic stop valves, it is evident that, if a tube blows out in any one boiler, the steam from the other boilers will discharge through the main into the damaged boiler and out through the ruptured tube. This sudden rush of steam to the disabled boiler will cause a rapid drop of pressure in the other boilers, and, as the pressure decreases in the boilers, a large quantity of water will be rapidly converted into steam at the lower pressure, thus causing violent waterhammer; in extreme cases, the result of this condition may even cause an explosion in one or more of the sound boilers. A sudden drop in pressure in a boiler causes water to be lifted over with the steam, and this water, flowing to the engines, may result in wrecking an engine. If a tube should blow out in a boiler that is properly protected by an automatic stop and check-valve, the automatic valve will close when the pressure in the boiler falls below that in the main.

Automatic Threading Lathe. The automatic type of threading lathe is especially adapted to threading duplicate parts in quantity, because the movements of the lathe are all automatically controlled after the work is placed in position and the lathe is started. This mechanical control, which governs the forward and return movements of the carriage and the movements of the tool, insures more rapid and continuous operation than would be obtained with an ordinary engine lathe.

Autothermic. Steel strips covered by aluminum sections for their entire length. Since aluminum expands more than steel due to temperature increases, the strips will assume a curved form when heated. Used in connection with high silicon-aluminum pistons in combustion engines to increase the expansion of the piston skirt in the direction parallel to the piston-pin, and to reduce the expansion along the diameter perpendicular to the piston-pin, thus causing a piston skirt ground oval when manufactured to assume a cylindrical form at engine working temperature.

Auto-Transformers. An auto-transformer has but one continuous winding which serves as both primary and secondary. A tap is brought off from some point in the winding and the voltage between this point and the end of the winding will be some fraction of the voltage between the terminals of the entire winding. Usually the ratio of primary to secondary is close to unity. This type of construction permits a considerable saving in copper over the conventional two-winding type of transformer. There is no insulation between the high- and low-voltage circuits, and therefore, the use of an auto-transformer is confined to those cases where this feature is not objectionable. Most of the

phase connections used with transformers are also possible with auto-transformers which are used wherever their primary and secondary voltages are near enough in value to make their use permissible. Auto-transformers are used for furnishing reduced starting voltages to synchronous or induction motors and rotary converters. With a variable tap switch to provide different ratios, they may be used as voltage compensators to provide the exact potential required for operating certain devices at maximum efficiency or accuracy.

Avogadro's Law. A principle in physics which states that equal volumes of all gases having the same temperature and subjected to the same pressure contain the same number of molecules.

Avoirdupois or Commercial Weight. 1 gross or long ton = 2240 pounds; 1 net or short ton = 2000 pounds; 1 pound = 16 ounces = 7000 grains; 1 ounce = 16 drachms = 437.5 grains.

1 ton (of 2240 pounds) = 1.016 metric tons = 1016 kilograms; 1 pound = 0.4536 kilogram = 453.6 grams; 1 ounce avoirdupois = 28.35 grams; 1 ounce troy = 31.103 grams; 1 grain = 0.0648 gram.

The following measures for weight are now seldom used in the United States: 1 hundred-weight = 4 quarters = 112 pounds (1 gross or long ton = 20 hundred-weights); 1 quarter = 28 pounds; 1 stone = 14 pounds; 1 quintal = 100 pounds.

Axiom. An axiom, in mathematics, is a self-evident general proposition which is accepted as true without a proof. The twelve axioms which are the foundation of geometry, and of the mathematical science in general, are: 1. Quantities which are equal to the same quantity are also equal to one another. 2. If equal quantities are added to equal quantities, the totals are equal. 3. If equal quantities are taken from equal quantities, the remainders are equal. 4. If equal quantities are added to unequal quantities, the totals are unequal. 5. If equal quantities are taken from unequal quantities, the remainders are unequal. 6. Quantities which are double the same quantity are equal to one another. 7. Quantities which are one-half of the same quantity are equal to one another. 8. Geometrical quantities which coincide with one another, that is, which actually fill the same space, are equal to one another. 9. The whole is greater than any of its parts. 10. Two straight lines cannot enclose a space. 11. All right angles are equal to one another. 12. If a straight line intersects two other straight lines, so as to make the two interior angles on the same side of it taken together less than two right angles, then these straight lines, if con-

tinually produced, must meet upon the side on which the angles are less than two right angles.

Axis of Equilibrium. In a floating body at rest on the water, a line joining the center of gravity of the body with the center of buoyancy. This line is always vertical. See Buoyancy.

Axle Lathes. Axle lathes are equipped with two tool carriages, so that both ends of an axle may be turned at the same time. On most lathes of this class, the axle is revolved by a special driving head, which is located in the center of the lathe bed. The axle is gripped in the middle by clamps on the head, and the ends are supported by tailstocks. With this arrangement, the work is rotated on "dead centers" (non-rotating centers), which is desirable, and the ends are accessible for the turning operations. The central driving head is operated through gearing from a shaft which extends along the bed and is rotated through additional gearing at the headstock end, either by a belt pulley or a direct-connected motor.

B

Babbitting Machine, Centrifugal. Babbitt can be cast in parts by means of a machine of the centrifugal type. This machine contains a rotating spindle which can be quickly started and stopped. On the front end of this spindle there is mounted a faceplate which carries a work-holding fixture. When a connecting-rod is being babbitted, it is located by a pin that fits the wrist-pin hole. The work is first cleaned and tinned and placed in the fixture before being allowed to cool. The spindle, faceplate, fixture and work are then rotated together, after which a measured quantity of molten babbitt is poured into the hole in the center of the outer fixture plate. As the babbitt cools, the centrifugal force throws it against the proper surface of the work, where it solidifies. This method of depositing babbitt in bearings obviates blow-holes and brings all impurities to the surface of the babbitt, from which they are removed in the first boring operation.

Babbitting Mandrel. An arbor or rod used when lining bearings with babbitt metal, the mandrel corresponding to the shaft which is to have its bearing in the lining.

Babbitt Metal. Babbitt is the name given to a large variety of white metal alloys used as linings for bearings. The name is derived from that of the inventor, Isaac Babbitt, who, in 1839, obtained a patent for a special type of bearing enclosing a soft metal alloy. The exact composition of the original babbitt metal is not known, but the ingredients were copper, tin, and antimony, in approximately the following proportions: 89.3 per cent tin; 3.6 per cent copper; and 7.1 per cent antimony. This metal possesses great anti-frictional qualities, but the high percentage of tin makes it expensive and has led to the substitution of other metals which are marketed under the name of "babbitt metal." These cheaper grades, when properly made, are superior to the original babbitt metal for some purposes. The composition of babbitt metal should be varied according to the pressure to which it will be subjected and the speed of the rotating member; the size of the bearing and thickness of the babbitt metal lining should also be considered. While it is not necessary to use a different composition for each slight variation, a different grade is preferable when the conditions are radically different.

Babbitt Metal for Heavy Pressures. The following composition gives a rather hard babbitt metal which may be used for

lining connecting-rod and shaft bearings subjected to heavy pressures. This composition conforms to the S.A.E. standard specification for No. 11 babbitt, and is suitable for die-castings.

Cast Products: Tin, minimum, 86 per cent; copper, 5 to 6.5 per cent; antimony, 6 to 7.5 per cent; lead, maximum, 0.35 per cent; iron, maximum, 0.08 per cent; arsenic, maximum, 0.10 per cent; bismuth, maximum, 0.08 per cent; zinc and aluminum, none.

Ingots: Tin, minimum, 87.25 per cent; copper, 5.5 to 6 per cent; antimony, 6.5 to 7 per cent; lead, maximum, 0.35 per cent; iron, maximum, 0.08 per cent; arsenic, maximum, 0.10 per cent; bismuth, maximum, 0.08 per cent; zinc and aluminum, none.

Babbitt Metal for Light Pressures. A cheap babbitt metal intended for large bearings and light service and which is also suitable for die castings, has the following composition, the figures representing percentages:

Cast Products: Tin, 4.50 to 5.50; antimony, 9.25 to 10.75; lead, maximum, 86.00; copper, maximum, 0.50; arsenic, maximum, 0.20; zinc and aluminum, none.

Ingots: Tin, 4.75 to 5.25; antimony, 9.75 to 10.25; lead, maximum, 85.50; copper, maximum, 0.50; arsenic, maximum, 0.20; zinc and aluminum, none.

This is the Society of Automotive Engineers (S.A.E.) specification No. 13. This metal should not be used as a substitute for a babbitt with a high tin content.

Babbitt Metal for Medium Pressures. A relatively cheap babbitt metal intended for bearings subjected to moderate pressures and one that is also suitable for die castings has the following composition, the figures representing percentages:

Cast Products: Antimony, 9.50 to 11.50; copper, 2.25 to 3.75; lead, maximum, 26.00; tin, minimum, 59.50; iron, maximum, 0.08; bismuth, maximum, 0.08; zinc and aluminum, none.

Ingots: Antimony, 10.25 to 10.75; copper, 2.75 to 3.25; lead, maximum, 25.25; tin, minimum, 60.00; iron, maximum, 0.08; bismuth, maximum, 0.08; zinc and aluminum, none.

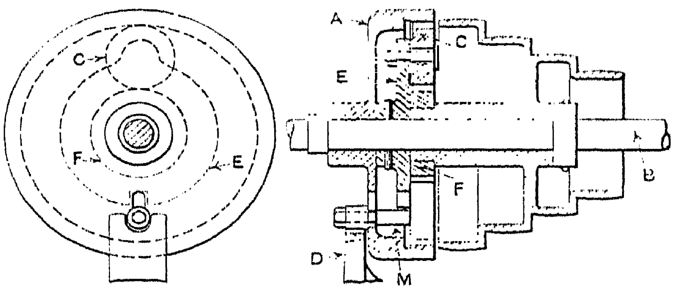
This is the Society of Automotive Engineers (S.A.E.) standard specification No. 12.

Back Cone of Bevel Gears. The back cone of a bevel gear is the cone generated by swinging the back cone radius about the axis of the gear. The *back cone radius* is the distance perpendicular to the pitch surface from the pitch line to the axis. (This distance is also called virtual pitch radius.)

Back-Gears. Back-gears are applied to various types of machine tools such as lathes, boring mills, drill presses, etc., in order to increase the range of speeds obtainable with a cone-pulley

drive. In the case of an engine lathe, if a slower speed is required than can be obtained with the belt on the largest step of the cone, the latter is disconnected from the spindle, and the back-gears are moved into mesh; the drive is then from the cone-pulley through the back-gears and to the spindle. The fastest speed with the back-gears in mesh is somewhat slower than the slowest speed when driving with the back-gears out of mesh.

Double Back-gearing: Many lathes have *double back-gears,* so that two ranges of speed may be obtained in addition to those secured by shifting the belt on the cone-pulley. For instance, if there are four steps on the cone-pulley, twelve changes of speed would be available if the lathe were equipped with double back-gears. These gears may be used merely to increase the number of speed changes, or the primary object of including double back-gears in the design of a lathe may be to increase the driving



Differential Back-Gearing

power without sacrificing, appreciably, the number of speed changes, by reducing the number of steps on the cone-pulley and increasing their width, so that a much wider driving belt may be used.

Triple-geared Headstocks: That type of gearing for lathe headstocks which has two back-gear shafts, one of which carries a pinion that may be engaged directly with an internal gear on the faceplate, is commonly known as *triple gearing.* This term, however, as used by different lathe manufacturers, is not applied to the same arrangement of gearing, and does not invariably mean that the number of speeds may be tripled.

Back-Gears, Differential Type. The planetary form of gearing in which one or more gears not only revolve about their own axes, but turn bodily about a meshing gear, is sometimes applied to speed-changing mechanisms. The illustration shows the application of a planetary gear to the cone-pulley on an upright drilling

machine for doubling the range of speeds the same as with ordinary back-gears; this form of mechanism is often called "differential back-gearing." The cone-pulley and the casting *A* are both free to rotate upon the shaft *B*. Gear teeth are cut on the inside of casting *A*, thus forming an internal gear. The planetary pinion *C* rotates upon a pin fixed in disk *E*, which is keyed to shaft *B*. The gear *F*, about which pinion *C* rotates, is fastened to the hub of the cone-pulley. The pin *M*, which may be clamped in a slot in casting *A*, serves to lock casting *A* and disk *E* together when placed in the upper end of the slot. When the pin is in this upper position, another slot in the disk *E* is engaged by the inner end of the pin. When this pin is lowered into engagement with the stationary arm *D*, casting *A* is held stationary. The speed changes are obtained in the following manner: When the direct drive and the faster range of speeds are required, pin *M* is moved up so as to lock casting *A* and disk *E* together; the shaft and cone-pulley then rotate at the same speed. When the casting *A* is held stationary and disk *E* is free to revolve, the motion is transmitted through gears *F* and *C* to disk *E*, and the shaft in this way is rotated at a slower speed. In order to secure this reduction of speed by transmitting the motion through the planetary gearing, pin *M* is lowered into engagement with arm *D*, thus locking casting *A*.

Backing Hammer. A type of sledge hammer used by blacksmiths for the very lightest work for which a sledge hammer would be required; the backing hammer generally has a ball-peen end like a hand hammer.

Backing-Off. See Relieving.

Backlash. The lost motion between two machine parts which transmit motion one to the other is often called backlash. This term is applied to lost motion between gear teeth, between cams and their followers, between screws and nuts and other adjacent parts.

Back Pitch of Riveted Joint. The distance between the center-lines of any two adjacent rows of rivets is sometimes called the "back pitch." This distance, which is measured at right angles to the direction of the joint, should be at least twice the diameter of the rivets for boiler work. Where a single rivet in the inner row comes midway between two rivets in the outer row, the sum of the two diagonal sections of the plate between the inner rivet and the two outer rivets should be at least 20 per cent greater than the section of the plate between the two rivets in the outer row.

Back Pressure. This is the pressure in a steam engine cylinder when the exhaust port is open, and is that against which the

piston is forced during the working stroke. The *working pressure* varies throughout the stroke, due to the expansion of the steam, while the back pressure remains practically constant, except for the effect of compression at the end of the stroke. The theoretical back pressure in a non-condensing engine (one exhausting into the atmosphere) is that of the atmosphere, or 14.7 pounds per square inch above a vacuum, but, in actual practice, it is about 2 pounds above atmospheric pressure, or 17 pounds absolute, due to the resistance of exhaust ports and connecting pipes. In the case of a condensing engine (one exhausting into a condenser), the back pressure depends upon the efficiency of the condenser, averaging from 1 to 3 pounds absolute pressure in the best practice.

Back-Rest. Any support employed in machine tools for supporting revolving work, and specifically applied to rear supports for long, slender shafts or similar work while being turned or ground.

Bagasse as Fuel. Bagasse is the fibrous portion of the sugar cane left after the juice has been extracted. A pound of bagasse, as it comes from the press, has a heating value of approximately 3400 B.T.U., or about 4.25 pounds are required to equal 1 pound of coal. In burning this fuel with mechanical draft, an air supply of 200 cubic feet of air per pound is required. This gives better results than if burned under a natural draft, as smaller flues and chimney may be employed and a better mixture of the air and gases is secured in this way. An induced draft with the equivalent of from 1- to 1¼-ounce pressure seems to give the best results. Under a natural draft, about 270 cubic feet of air are required per pound of fuel.

Baily's Metal. Baily's metal is an alloy composed of 82 per cent of copper, 13 per cent of tin, and 5 per cent of zinc, which was used for making the standard imperial yard of Great Britain and the standard yard of the United States in the Bureau of Weights and Measures. It has also been used for making nearly fifty copies of the standard yard supplied by the British government to foreign governments and public institutions.

Bakadie. Alloy steel which, after heat-treatment, has a surface hardness of from 63 to 65 Rockwell, and at the same time, has an unusually tough core. The hardness insures good wearing properties and high resistance to abrasion. Intended especially for use in making molds for producing synthetic plastic parts. Especially suitable for molds in which the impressions are "hobbed."

Bakelite. Phenolic resinoid plastics (commonly designated by the trade name "Bakelite") were invented in 1907 by Dr. L. H.

Baekeland. Like most products of creative chemistry, phenol resinoid bears no resemblance to the raw materials from which it is made. Principal among these raw materials are phenol or "carbolic acid," a white crystalline solid, and formaldehyde, a gas, which when dissolved in water is commonly known as formalin. Both are highly reactive substances. Under certain definite, controlled conditions they may be caused to combine chemically, forming a distinctly new and highly useful product, a product which is resin-like but superior in its properties to any natural resin. In its raw, or primary state, phenol resinoid is quickly softened by moderate heat, and is soluble in certain solvents, notably alcohol. Further heating, however, causes it to harden, after which it cannot again be softened at any temperature. Furthermore, the solvents which served to dissolve it in its primary state now have little or no effect on it. This property of being first fusible and soluble, and then, under the influence of heat, becoming infusible and insoluble—of becoming, in fact, a material of pronounced hardness, strength, and resistance to deteriorating agents generally, has made phenol resinoid outstanding among organic plastic materials. It is called a resinoid to distinguish it from natural resinous substances. Bakelite plastics may be classified generally in the following groups:

1. Molding Materials.
2. Coating Materials.
3. Impregnating Materials.
4. Cements.
5. Bonding Resins.
6. Synthetic Resins for Air-Drying Finishes.
7. Cast Resinoids.
8. Resinoid Varnishes for the Production of Laminated Materials.

Molding Materials: These materials are furnished in powder, flake, granular, board and blank form. For compression molding in hardened steel molds under pressure varying from 2,000 to 8,000 lbs. per square inch at temperatures ranging from 270° F., to 350° F., cooling used depending upon type of material. *Thermoplastic* types are also injection molded hot at temperatures ranging from 325° F. to 425° F.—mold temperatures ranging from room temperature to 200° F., depending upon type and material used. Molded materials are used for electrical insulation, mechanical parts, radio parts, hardware, packages, closures, displays, toys, and novelties. There are many varieties of Bakelite molding materials which have been developed for special conditions of use such as for molded parts which require an unusually high degree of heat, water, or shock resistance, elasticity or brilliant finish and color.

Coating Materials: Varnishes and enamels (baking) are heat-reactive coating materials for electrical coils, windings, armatures and insulation. They are non-hygroscopic, unaffected by

extremes of climate, impervious to oils, water, solvents and most chemicals. Effective as insulating coatings because of their dielectric strength, hardness and resistance to heat; also effective as chemical protective coatings for tanks, machinery or any other equipment that may be subjected to erosion or chemical corrosion. They are hardened by baking at temperatures from 170° F. to 300° F. for from several minutes to several hours, depending upon the nature and size of the part being coated.

The lacquers provide hard, transparent coatings for highly finished metal. They are resistant to solvents, gases, water and perspiration. Baked, after application, at 275° F. for twenty minutes. Used for coating metal hardware, precision instruments, vanity cases, belt buckles, mechanical pencils and ornaments.

The calendering materials are special flexible resinoids for coating fabrics or similar materials which are rendered chemical, heat and weather resistant.

Liquid resinoid products are used for impregnation of coils, fabrics or other products to improve their dielectric qualities, chemical resistance, durability and heat resistance. They are used for such purposes as brake lining, armatures, insulating cambric and cable coverings.

Cements: Air drying cements and adhesives are for bonding plywoods and veneers. These adhesives are flexible to rigid in range and have high bonding strength.

Heat hardenable cements provide an extremely hard and tenacious bond which is exceptionally resistant to heat, solvents, and most chemicals. They are employed extensively for cementing together the bulbs and bases of electric lamps and electronic tubes and for bonding wood, porcelain, glass, metal and Bakelite materials. They require baking at 250° F. for several hours.

Bonding Resins: These materials include a variety of resins for either the cold molding or hot molding process. They are used as bonds for abrasive wheels, carbon brushes, phenolic cold molded pieces, resistors, etc. The bonds have good mechanical strength, and are heat resistant and chemical resistant.

Resins for Air-Drying Finishes: Synthetic resins are oil-soluble and oil reactive, quick-drying resins, which have made possible a series of durable paints, varnishes and enamels. They are durable, waterproof, resistant to dilute acids, weak alkalies, solvents, and chemical agents. Finishes made from these resins do not require baking.

Cast Resinoids: These materials are obtainable in a variety of brilliant transparent, translucent, mottled and opaque colors. They can be machined readily, engraved and polished. They are

used for costume jewelry, pencils, paper weights, buttons, buckles and many other decorative and industrial applications.

Cast resinoids are readily machined. They are resistant even to the destructive effects of hydrofluoric acid and are used for laboratory equipment such as beakers, graduates and bottles and, also, for electrical insulation. The material is highly non-hygroscopic and has low power-loss characteristics.

These materials are available in transparent, translucent, mottled and opaque effects.

Varnishes for Laminated Materials: Laminated products are fabricated from superimposed layers of paper, canvas, cotton duck, or asbestos fabric impregnated which Bakelite resinoid varnishes and hardened by heat and pressure into a solid, homogeneous state. They are characterized by unusual strength, resiliency and toughness; possess high dielectric strength; exceptional resistance to heat, water, oil and most chemicals. These laminated materials can be machined, punched and polished. They are produced in a variety of sheets, tubes and rods, which are obtainable in special dimensions and sizes. Sheet stock is produced in many solid colors, light shades and the wood-grain and marble simulations. Bakelite laminated is employed extensively for radio and electrical insulation, wall paneling, wainscoting, baseboard trim, table and desk tops, instrument panels, refrigerator breaker strips, silent automotive timing gears, industrial gears and pinions, and roll neck bearings in steel mills.

Bakelite Polystyrene. A thermoplastic molding material that was primarily developed for use as an electrical insulator. Tests made indicate that no noticeable changes occur in the electrical properties of the material with an increase in either temperature or humidity. Tensile strength, from 5000 to 5500 pounds per square inch; impact strength, from 0.14 to 0.16 foot-pound. Since the material was developed primarily as an electrical insulator, it offers marked advantages for use in many electrical products and equipment.

Balanced Draft. A system of forced mechanical draft employed for boiler furnaces in which a special damper is placed in the smoke outlet from the furnace, this damper being controlled by an automatic regulator operated in connection with the draft fan. This combination maintains a pressure within the furnace equal to that of the surrounding atmosphere and limits the volume of air introduced to that required to effect complete combustion, the draft being balanced by throttling the suction of the chimney in exact proportion to the speed of the blower.

Balanced Slide-Valve. See under Slide-valve.

Balancers. Balancers, also known as "direct-current compensators," consist of a combination of two or more direct-current machines coupled directly to each other, and connected in series across the conductors of a multiple-wire system of electric current distribution. The object of balancers is to maintain the potentials of the intermediate wires of a system, which are connected to the junction points between the machines. When two machines are used, each carries one-half the line voltage; they are then generally employed to provide the neutral of a three-wire lighting system.

Balancing. The rotating parts of many machines must be balanced in order to prevent excessive vibrations, especially if the speed of rotation is high. Balancing may be done either by adding a counterbalancing weight or weights to the rotating part, or by removing metal from the heavy or unbalanced side. In the case of reciprocating steam engines, it is the general practice to add a weight opposite the crank in order to counteract, as far as possible, the unbalancing effect of the crank and its connecting-rod. The weight necessary for counterbalancing is calculated by the engine designer in accordance with the various factors involved, and this balancing weight is usually incorporated in the design of the crank, so that it forms an integral part of it. In the construction of fast-running machinery of various kinds, balancing is often necessary because of slight weight variations at different points around the circumference of such parts as flywheels, cylindrical drums, disks, etc. The balancing of such parts involves locating the unbalanced side and either counterbalancing it or removing the excess weight, in order to prevent excessive vibrations at high speed. The excess weight which causes the lack of balance may be very slight, as the vibrations are due to the action of centrifugal force when this unbalanced mass is rotated rapidly. The effect of such vibration may be to injure the entire mechanism of which the rotary member forms a part, and the product of machinery of the manufacturing type is also injuriously affected in many cases. For instance, if the wheel-spindle of a cylindrical grinding machine is out of running balance, the resulting vibrations will cause chatter marks on the work. The importance of balancing fast revolving parts has also been demonstrated in connection with many other types of machine tools as well as other classes of machinery, and balancing of machine parts on a commercial basis has been made possible by the development of balancing machines.

Static or Standing Balance: If a circular part, such as a cylindrical drum or pulley, were mounted in bearings in which friction was practically eliminated, and with the axle in a hori-

zontal position, it is evident that if one side were even slightly heavier than the other this unbalanced side would be at the bottom or lowest point possible when the drum or pulley came to a state of rest. If this same part were brought to such a state of balance that it would remain standing when turned about its axis to any position, it would be in *standing* or *static* balance; it does not necessarily follow, however, that this part would be in a balanced state when revolving, although if it has a running balance it will also be balanced statically.

Running or Dynamic Balance: If the rotating part is in the form of a thin disk, static balancing, if carefully done, might be accurate enough for high speeds, but if the rotating part is long in proportion to its diameter, and the unbalanced portions are at opposite ends or in different planes, the balancing must be done so as to counteract the centrifugal force of these heavy parts when they are rotating rapidly. This is known as a *running* balance or *dynamic* balancing. Theoretically, to obtain a perfect running balance, the exact position of the heavy sections should be located and the balancing effected either by reducing their weight or by adding counterweights opposite each section and in the same plane at the proper radius; but, if the rotating part is rigidly mounted on a stiff shaft, a running balance that is sufficiently accurate for practical purposes can be obtained by means of comparatively few counterbalancing weights located with reference to the unbalanced parts.

Balancing Machines. Several types of machines have been developed for testing the running or dynamic balance of machine parts. Some balancing machines are designed primarily for wheels, disks and comparatively narrow face parts, whereas others are arranged to test various classes of work, such as crankshafts, rotors of generators and motors, pulleys, spindles, etc. Balancing machines are widely used by motor car manufacturers for testing the crankshafts, by electrical machinery manufacturers, and in various other fields, particularly when rotative speeds are high and the requirements are exacting in regard to vibration.

Balancing machines are designed to indicate unbalance and where corrections are required. The Gisholt "Dynetric" balancing machine supports the part to be balanced, freely or so that it is not restrained at either end. The correction for unbalance is indicated directly at the points where corrections are to be made, and without stopping the machine. It is indicated electrically, no optical or mechanical levers or devices being used. Only two switches are employed to obtain the amount and angular positions of corrections required in both correction planes. The machine measures either static or dynamic unbal-

ance, or the combined effect of both in two arbitrarily selected planes of correction.

A balancing machine which has been developed by the research laboratory of the Westinghouse Electric & Mfg. Co. may be used for balancing rotors "on location"—that is, when already assembled in their respective machines. This portable balancing outfit reduces the number of trial runs to two or three, and simplifies the determination of the exact correction weight position. The work of balancing is reduced to simple meter readings and elementary arithmetic. The equipment is provided with a vibration pick-up that is held against the vibrating body.

The General Electric Co. has developed a portable dynamic balancing instrument capable of measuring the amount and phase angle of unbalance vibration in the bearing pedestals of a rotating machine running in its own or substitute bearings at any speed between approximately 600 and 5000 R.P.M. Being portable, it permits balancing rotating equipment without removing the rotor from the machine. In balancing, a sine-wave alternator spindle is inserted in a lathe center hole in either end of the rotor of the machine to be balanced, and the vibration pick-up is placed against the rotor bearing. The two voltages generated in the sine-wave alternator and vibration velocity unit are applied to the measuring instrument. The amount of vibration and the relative angular position of the high spots are then determined. This measurement is made with the machine in its original condition and also with two trial weights attached. From these measurements, calculations are made to determine the amount and location of the weights to be applied for correcting the unbalance.

Ball Bearing Lubrication. To obtain the full measure of efficiency and service from ball and roller bearing equipment, the kind and quality of the lubricant, as well as the system of applying it, must be adapted to the design of the bearing, the design of the machine, and the operating conditions.

Operating Temperatures: Under ordinary conditions the temperature of a bearing while running will be from 10 to 60 degrees F. above that of the room. If it exceeds 125 degrees F., ordinary greases will frequently prove unsatisfactory. They will tend to soften and flow continuously into the path of the rolling elements, causing a rise in the normal operating temperature due to the increased frictional resistance introduced. This may eventually result in the separation of the oil and soap base, with a complete loss of lubricating qualities. In some cases, greases developed for use at high temperatures may be employed. Care should be taken, however, to see that they meet all the requirements for adequate lubrication.

Mineral oil of proper physical and chemical properties is an ideal lubricant for ball and roller bearings when the housing is designed to control the quantity entering the bearing and to prevent leakage and protect the bearing from the entrance of foreign matter. A ball or roller bearing should not be subjected to temperature in excess of 300 degrees F., because of the danger of drawing the temper of the hardened steel races and balls.

Quantity of Lubricant Required: In no case does a ball or roller bearing require a large quantity of lubricant. On the contrary, a few drops of oil, or a corresponding amount of grease, properly distributed over the running surfaces of the bearing, will provide satisfactory lubrication for a considerable period of time. A large volume of lubricant within a bearing will usually result in high operating temperatures, due to the working or churning of the lubricant by the rolling elements and retainer. This may seriously impair the useful life of the lubricant through oxidation or sludging of the oil or actual disintegration of greases.

Use of Grease: If grease is used, the housing should not be kept more than one-fourth to one-half full of the lubricant. Unlike oil, there is no way of controlling with any degree of exactness the quantity of grease in a housing, and greater care must therefore be taken to avoid overloading. A bearing that runs at too high a temperature will often return to normal temperature if some of the lubricating grease is removed.

Grease is being used successfully for the lubrication of ball bearings at high speeds, but great care is necessary, both from the standpoint of housing design and selection of the lubricant, in order to obtain satisfactory results. Any system employed must be designed to feed only a limited amount of grease to the bearing. For the average application at operating speeds up to 3600 revolutions per minute, a grease of soft consistency, such as a No. 2 grease, will usually be found satisfactory, provided it is suitable in other respects. Hard greases, such as No. 3, may be used if the grease is to serve as a packing medium around the shaft to prevent the entrance of dirt, water, or other corrosive substances.

Sealed Bearings: Bearings for certain classes of service must operate over long periods without relubrication, as, for example, a motor installation on an airplane beacon; hence the efforts of ball-bearing manufacturers to produce bearings so completely sealed as to enable them to retain their original charge of grease for many months. In appreciation of this requirement, the petroleum industry has developed lubricants that will maintain lubrication for a long period without change in structure, homogeneity, lubricating properties, or leakage.

Ball Bearings. Ball bearings are designed to provide rolling contact between a rotating shaft or other part, and its supporting members, instead of sliding contact as with plain bearings. Ball bearings are used in preference to sliding bearings principally for the following reasons: There is less loss of power on account of the lower coefficient of friction; the friction of a ball bearing is independent of the viscosity of the lubricant or its temperature; the frictional resistance at starting is very much less than in a sliding bearing; ball bearings are much shorter and more compact than sliding bearings; the scraping and fitting of bearing linings is not necessary; the danger of heated bearings is practically eliminated; a bearing of proper construction can adjust itself to deflections of the shaft; the wear is practically negligible.

Ball bearings may be divided into two main types: *radial* bearings and *thrust* bearings. The former are designed primarily for loads at right angles to the shaft axis, and the latter for axial loads. All radial bearings, however, will withstand thrust loads, and those properly designed for angular contact may resist thrust loads which are equal to or greater than the radial load.

Angle of Contact and Thrust Capacity: Figuring the capacity of a ball bearing under combined loads is complicated as it is a function of the maximum safe ball load, the angles of contact and of load application, as measured from the plane of the balls, and also the center angle between the balls. As the pure thrust capacity of the bearing is increased by enlarging the angle of contact, there is a reduction in pure radial capacity. For example, a bearing having an angle of contact of 10 degrees will carry, as thrust, 77 per cent of its radial capacity, whereas its radial capacity is reduced 1.5 per cent. Again, a bearing having an angle of contact of 30 degrees will carry, as pure thrust, 252 per cent of its radial capacity, and has a loss of 13.4 per cent in radial rating.

Any ball bearing under combined loads becomes an angular contact bearing. This angle of contact can either be incorporated in the design or obtained by deformation of the parts under load. In other words, what is known as an annular bearing becomes an angular contact bearing when thrust is applied. Under pure radial load, the contact between the balls and races is in line with the applied load and at right angles to the shaft, but as soon as thrust load is applied, the contact becomes angular and is caused by motion between the inner and outer races until the material is deformed sufficiently to resist the load.

Percentages of Radial and Thrust Loads: There are three types of bearing that are combined load carriers: First, the annular ball bearing, which is primarily designed for radial loads

and has no angle of contact incorporated in its design, therefore having minimum thrust capacity (approximately 20 per cent of its radial capacity). Second, the one-direction angular contact bearing, which has a thrust capacity depending upon race design and the angle incorporated, which is generally made so that the thrust capacity is 100 per cent of the radial capacity. (This bearing, however, when used for combined loads, can only be used in pairs, and must have a threaded or shim adjustment incorporated in the mounting design to allow for initial adjustment.) Third, the double angular type bearing which is really two of the previously mentioned bearings built as a self-contained unit. The funtioning of this bearing is not dependent on any exterior adjustment, and the angle of contact is generally such that it will sustain approximately 150 per cent of its radial capacity as thrust.

Ball Bearings, Mounting. If the bearing is to carry a radial load without thrust, the inner race should have a light driving fit on the shaft and be securely clamped against a shoulder by a nut or clamping device which is proof against jarring loose. The outer race of a bearing subjected to a radial load only should fit closely in its retaining box or housing, but be free to "float" or shift in an endwise direction. When the outer race is mounted in this way, it will align itself with reference to the inner race and will tend to have a slow intermittent creeping movement, insuring a proper distribution of the load over the entire surface of the outer race.

If there are several radial bearings on the same shaft, the end-thrust in both directions should be taken by the same bearing, and the outer races of the other bearings should be free to locate themselves. It is considered good practice, when two bearings are mounted on one shaft, to prevent axial thrust by making the inner race of each bearing a light driving fit on the shaft. The outer race of one bearing has a sliding fit in its seat and is given a slight amount of axial play (say, from 0.010 to 0.020 inch); the outer race of the other bearing is also made a sliding fit, but is allowed considerable axial play. The first bearing takes the radial load and end-thrust, and the second bearing, a radial load only.

Ball-Burnishing Process. Burnishing, according to one meaning of the word, consists in finishing the surfaces of work by rubbing with a highly polished steel hand tool, which hardens and polishes the surface metal. The ball-burnishing process produces the same effect, but in an entirely different manner, employing quantities of hardened and polished steel balls which are caused to roll over the work while under pressure. This

pressure is effected by the weight of the balls which are confined within a tumbling barrel. Each ball thus acts as an individual burnishing tool, and as it rolls over the work, pressed by the mass of balls and work above, it leaves a burnished path on the work.

To burnish a quantity of work, the work and balls are placed in the barrel, water is then added until the contents of the barrel are covered. In this water, about four ounces of burnishing soap chips have previously been dissolved. The handhole covers are then clamped in place, and the mixture tumbled from one to five hours, depending upon the character of the work, metal, etc. The speed ordinarily employed for tumbling ranges from 10 to 30 revolutions per minute, the usual speed being 15 revolutions per minute. After the work has been burnished sufficiently, it is separated from the balls by dumping the mixture into a screen of sufficiently coarse mesh to allow the balls to drop through.

Instead of steel balls, small round steel punchings that are ordinarily a scrap by-product when holes are punched in steel articles, may be employed in the tumbling barrels. These steel punchings are first tumbled with no work in place, and then, after the corners are well rounded, the work is put into the tumbling barrel. It is claimed that the burnishing effect is almost as good as that obtained when hardened steel balls are used, while the cost of the punchings is almost negligible.

Ball Classification. Ball-bearing balls are graded in four main classes, known as "alloy," and A, B, and C grades. Alloy steel balls have the greatest crushing strength and do not vary in size more than 0.0001 inch. Balls classified as A-grade are made from high-grade tool steel and do not vary over 0.001 inch above or below the exact dimension. Balls known as B-grade are the seconds taken from the two higher grades mentioned, and do not vary more than 0.002 inch above or below the exact dimension. The C grade, commonly known as hardware balls, are those picked from the higher grades when these show a defective surface. They may or may not be as accurate as to size as the other grades, according to the use to which they are to be put.

Ballentine Hardness Test. In the Ballentine hardness testing method, a hammer of specified weight is permitted to fall through a specified height on an anvil to which is connected a pin which rests on the specimen to be tested. Instead of measuring the indentation in the material tested, as in the Brinell hardness testing method, the resistance encountered is measured instead. This resistance is measured by the blow of the hammer

being transmitted to the test pin through a soft metal recording disk located at the lower end of the hammer, which will be indented to a depth varying in proportion to the resistance the pin encounters in indenting the material to be tested. The recording disk is usually made from lead.

Band Saw. This term is commonly applied to a machine consisting principally of a band saw in the shape of a flexible ribbon passing over two large pulleys, similarly to a belt, and a table through which the saw passes and upon which the work to be sawed is laid. Band saws are used for cutting wood, especially along curved or irregular lines. Some machines of the band-saw type are also intended primarily for cutting metal.

Band-Saw Speeds. Band-saw speeds for cutting wood vary from about 4700 feet per minute to 10,000 feet per minute, according to the conditions under which the saw is used. Small band saws—that is, those 2 inches and smaller—are used at a linear speed of about 4700 feet per minute. These saws are usually run over wheels about three feet in diameter, at a speed of 500 R.P.M. For larger band saws, the speeds depend mainly upon the kind of wood being sawed. For seasoned hard wood and for unseasoned, exceedingly hard wood, a saw speed of 7000 feet per minute is recommended. Such exceedingly hard wood would be frozen maple, for example, which is cut extensively in the mills of northern Wisconsin and Michigan. For seasoned, comparatively hard wood and unseasoned hard wood, such as maple, hickory, etc., a speed of 8000 feet per minute is recommended. For seasoned soft wood and unseasoned, comparatively hard wood, such as oak, a speed of 9000 feet per minute is recommended. For cutting the softest materials, such as unseasoned pine, bass wood, etc., a maximum speed of 10,000 feet per minute is recommended.

Band Saws for Metal Cutting. The band saws used for cutting-off bar stock and for other metal-cutting operations are similar to the band saws used in wood-working, in that the saw is in the form of a continuous band or belt which passes over revolving pulleys. The metal-cutting band saws, however, are equipped with some kind of mechanism for feeding the saw, and the driving mechanism is so arranged that the return side of the saw will clear a long bar of stock.

Barff Process. A method for producing a magnetic oxide on iron or steel, in order to protect it from the corrosive effects of air and moisture. See Bower-Barff Process.

Barium. Barium is one of the metallic chemical elements, the chemical symbol of which is Ba. Its atomic weight is 137.4. The

specific gravity of barium is 3.75; its melting point, 850 degrees C. (1562 degrees F.); and its electric conductivity (silver = 100), 30.61. Barium, as a metal, is expensive. The various salts formed by barium, however, are inexpensive. It occurs chiefly in the form of barytes, or heavy spar, and witherite. It is a metal difficult to obtain in pure form. The metal possesses a silver-white luster, but is very easily oxidized on exposure. It is slightly harder than lead. One of the most important uses is in the barium salts, which are frequently used for heating baths for metals to be hardened. Barium chloride ($BaCl_2 + 2\ H_2O$) is especially valuable for this purpose.

Barium Carbonate. A carburizing material used in combination with wood charcoal for increasing the carbon content of the surface of low-carbon steel, so that the steel may be case-hardened. A carburizing mixture contains 40 to 60 per cent, by weight, of barium carbonate, the remainder being wood charcoal.

Barium-Chloride Heating Baths. High-speed steel requires to be heated to a much higher temperature for hardening than does ordinaryy carbon steel. While a heat of from 1400 to 1600 degrees F. is sufficient for tools made from carbon steel, a heat of from, at least, 1800 to 2200 degrees F. is required in order to satisfactorily harden high-speed steel tools. The ordinary lead bath commonly used for heating carbon steel tools cannot be used at such high temperatures as these, and as it is, in general, unsatisfactory to heat the tools in an oven furnace, owing to the difficulty of correctly determining the hardening temperature when the tools are heated in this way, some heating medium has been sought which could stand high temperatures and in which the pieces to be hardened could be immersed so as to obtain a uniform heat without danger of burning delicate points or cutting edges—a danger which is always present when high-speed steel tools are heated to a high temperature in an open heating furnace. A temperature up to 2200 degrees F., and even higher, can be obtained by the barium-chloride bath.

The hardening of high-speed steel in barium-chloride electrically heated baths has not always been satisfactory. In one series of experiments the results were good when the salt bath was new, but it appeared that the chemical composition of the salt bath in the electric furnace gradually changed, producing a soft surface on the steel which was quite noticeable when the salt bath had been in use for about a week. This softness of the surface was noticeable directly after the hardening, and not merely after the temper had been drawn. A certain sediment collected in the electric salt bath, and the color of the barium

chloride became darker. The same barium chloride melted in an ordinary graphite crucible retained its lighter color and, even after two full weeks' use, the hardening results were satisfactory. The amount of barium chloride used in the electric furnace was much greater than that required for doing the same amount of work in a graphite crucible.

Experiments made later in Sweden indicate that it is possible to obtain perfectly satisfactory results by hardening high-speed steel in electric barium-chloride baths. If silica brick or clay is used for the crucible, it will be found that there is no chemical action and that high-speed steel can be hardened without any soft spots on the surface. The risk of breakages in hardening also appears to be diminished, when there are no soft spots on the surface. The objectionable results, therefore, in the early experiments are almost certain to have been due to the character of the lining of the crucible and the chemical action of the electrically heated salt bath on this lining. When the proper kind of crucible is used, it appears that properly conducted hardening of high-speed steel in electrically heated salt baths cannot be surpassed by any other hardening method, as regards either the accuracy with which the temperature can be obtained and maintained, the hardness of the surface, or the freedom from hardening cracks.

Barium Chromate. A material used in paints for protecting iron and steel against corrosion; it is pale yellow in color and made by treating barium chloride with sodium chromate. On account of the impurities generally contained, its protective value is not very high.

Barium Sulphate. A material found in large quantities in nature, extensively used in paints for the protection of iron and steel against corrosion. It grinds in 10 per cent of oil. An artificial form known as *blanc fixe* may be made by precipitating a barium salt by a soluble sulphate. Both the natural and artificial product may contain acids, and should be tested for this before being used as a protective paint.

Barlow's Formula. One of the most commonly used formulas for calculating the strength of cylinders subjected to internal pressure is known as the *Barlow formula,* and is as follows:

$$t = \frac{\quad}{2S},$$

in which t = thickness in inches; D = outside diameter in inches; P = pressure in pounds per square inch; S = allowable tensile stress in pounds per square inch.

Barograph. A form of *barometer* for measuring the pressure of the atmosphere, which does not employ mercury or other liquids as does the ordinary barometer. Other forms of a barometer of this class are aneroids and baroscopes.

Barometer. The barometer is an instrument for measuring the pressure of the atmosphere. In its simplest form it consists of a tube about 36 inches long, hermetically closed and having a vacuum at the upper end, and containing mercury. Two types of this form of barometer are made. In the *cistern* barometer, the tube is placed with its open lower end in a vessel containing mercury, the pressure of the atmosphere being measured by the difference of the height of the mercury in the tube and in the cistern. In the *siphon* barometer, the tube is bent at its lower end into a U-shape. The pressure of the atmosphere is read off as the difference of the levels of the mercury in the two vertical tubes of the U. Various forms of barometers which do not employ mercury or other liquids are also made, known as *aneroids, baroscopes, barographs,* etc. Normal atmospheric pressure is assumed to exist when the difference between the two levels of mercury in the barometer is 29.92 inches (760 millimeters).

Barometric Aerometer. An instrument for ascertaining the specific gravity of liquids, consisting of a vertical U-tube, with open ends, mounted upon a stand. The method in which it is used is as follows: Water is poured into one branch of the tube and the oil or liquid the specific gravity of which is to be measured is poured into the other. The vertical parts of the tube are provided with graduations and the relative height of the water in the one leg of the U, and the liquid in the other, indicates the specific gravity. See Aerometer.

Barometric Condenser. A barometric condenser which is also known as siphon condenser, is a device for condensing the exhaust steam from engines or turbines, by mixing the exhaust steam directly with the condensing water. This type of condenser is well adapted to plants in which the condensing water is suitable for being fed directly to the boilers and also for plants where only the condensation of the steam is desired and where the water of condensation is not used again.

Baroscope. A form of *barometer* for measuring the pressure of the atmosphere, which does not employ mercury or other liquids as does the ordinary barometer.

Barrel Converter. A converter similar to a Bessemer converter, used in the refining of copper by the *Manhes process.*

Baryte. A barium sulphate used in paints for protecting iron and steel against corrosion; see Barium Sulphate.

Barytes Cement. An acid-proof cementing material composed of pure, finely ground sulphate of barium made into a putty with a solution of silicate of soda. This solution sets very hard when heated and is then proof against acids. The specific gravity of the silicate of soda should be between 1.2 and 1.4, or from 24 to 42 degrees Baume; if too thin, the cement will not hold; if too thick, it will expand and break.

Basaloy. Non-shrinking, non-expanding metal alloy with a melting point of 255 degrees F. Suitable for making small master patterns. Since the alloy is non-shrinking, there is no difference in size between the original and the base-alloy pattern.

Base in Chemistry. A chemical base is a compound which will react with acids to form salts. It generally consists of a combination of a metal with oxygen. All bases that dissolve in water are known as *alkalies.*

Base Circle of a Gear. There are various curves which might be applied to gear teeth in order to secure rotation between two gears having intermeshing teeth, but the involute curve is used almost universally because it has certain practical advantages. If a circular disk were placed upon a drawing-board, an involute curve would be described by the end of a taut line when the latter was unwound from this disk. The disk represents what is known as the *base circle,* because it is from this circle that the involute is derived. The base circle must always be smaller than the pitch circle, in order to obtain involute tooth curves which meet practical requirements. A tooth curve cannot extend below the base circle from which it is derived.

The ratio of gearing depends upon the diameters of the pitch circles, the sizes of which are proportional to the numbers of teeth in the pinion and gear. The base circles must also be proportioned according to the same ratio. For example, if the *pitch diameter* of a gear or the diameter of its pitch circle is four times that of the pinion, the base circle of the gear must also be four times as large as that of the pinion base circle. The diameters of these base circles may be changed, but they must always remain proportional to the velocity ratio the same as the pitch circle diameters.

Base Circle Radius. To find the base circle radius, multiply the pitch circle radius by the cosine of the pressure angle.

For example, if a gear has 20 teeth of 1 diametral pitch and a pressure angle of $14\frac{1}{2}$ degrees, the pitch radius = 10 inches. Then

$$\text{Base circle radius} = 10 \times 0.96815 = 9.6815 \text{ inches.}$$

Basic Bessemer Process. See Bessemer Process.

Basic Dimension. The basic size of a screw thread or machine part is the theoretical or nominal standard size from which variations are made, as in the case of fitted parts which must have an allowance for providing a certain class of fit. The use of the hole diameter as the basic diameter has practical advantages in obtaining different classes of fits, especially when it is economical to finish holes by means of standard tools. For example, assume that holes are to be finished by reaming, and that shafts or plugs are to be fitted into them, this being a common condition in connection with various machine-building operations. If the diameter of the hole is basic, its size, within a small tolerance, may be maintained readily by the use of proper reaming equipment, and the diameter of a shaft or plug may be varied much more readily than that of the hole, in order to obtain the allowance for whatever class of fit is desired; therefore, different kinds of fits in holes finished by the same reamer may be obtained merely by grinding the shaft or plug to a diameter which gives the proper fit allowance. In the case of threaded holes, the tap is usually solid or non-adjustable, whereas dies ordinarily may be adjusted readily to obtain different classes of fits.

As both the hole and shaft or plug would ordinarily be given a certain tolerance, the basic dimension of a hole (except for forced fits) should be the minimum limit or diameter, there being a plus tolerance, and the nominal dimension of a shaft or plug should represent the maximum limit or diameter, there being a minus tolerance. The advantage of this method is that the minimum clearance between hole and shaft, or the "danger zone," is indicated by a direct comparison of the basic hole diameter and the nominal shaft diameter; the direction of the tolerances is such as to increase this clearance. For a forced fit, the basic hole size is the maximum diameter, the tolerance being minus, and the nominal shaft size is the minimum diameter, the tolerance being plus; consequently, the minimum fit allowance or interference between hole and shaft (or the "danger zone" for a forced fit) is indicated by a comparison of the basic hole diameter and the nominal shaft diameter. In this case the direction of the tolerances increases the interference or forced fit allowance. When it is economical to use cold-drawn or other commercial stock without machining then the maximum shaft size should be basic.

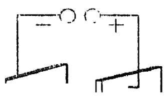
Basic Firebrick. A firebrick in which alumina predominates.

Basic Pig Iron. A term applied to pig iron containing so little silicon and sulphur that it is suited for easy conversion

into steel by the basic open-hearth process (restricted to pig iron containing not more than 1.00 per cent of silicon).

Basic Salt. In chemistry, a basic salt is formed when all the hydrogen has been removed from an acid and yet some of the base remains.

Batteries. The apparatus for transforming chemical energy into electric energy is known as a *primary cell.* Two or more of these cells joined together form a *primary battery,* although the term "battery" is frequently applied to the single cell as well. A primary cell consists of a liquid, known as the *electrolyte,* and two metals called the *elements* or *electrodes.* The action of the primary cell depends on the decomposition of the electrolyte, and the effect of the parts of the liquid on the electrodes. That electrode on which the electrolyte acts the more vigorously is termed the *positive,* or *anode,* and is indicated, by a + sign, since the current is flowing away from it into the electrolyte; the other is termed the *negative,* or *cathode,* and is indicated by a — sign, since the current is flowing into it from the electrolyte. But the current flows out into the wire from the pole or terminal joined to the negative electrode and, hence, that terminal is called positive; while the negative pole of the cell, joined to the positive electrode, is so called because the current is flowing into it from the wire.



Simple Voltaic Battery

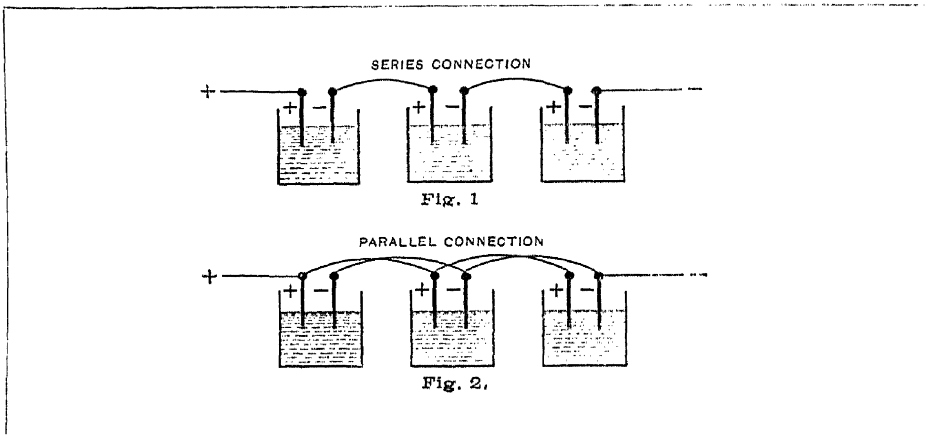
In the simple voltaic cell, shown in the illustration, dilute sulphuric acid (H_2SO_4) is used as the electrolyte, and copper and zinc strips as the electrodes. When these electrodes are connected externally, the radical SO_4 of the sulphuric acid, which has a greater affinity for zinc than for copper, combines with the zinc, and the hydrogen appears at the copper electrode, and an electric current will flow through the conductor and the cell. A similar action occurs in all other cells, but the radical liberated depends on the electrolyte and the electrodes used.

In *dry cells,* which now constitute over 90 per cent of the primary batteries in use, the electrolyte, instead of being in liquid form, is carried by some absorbent material or combined with some gelatinous substance, so that, no matter in what position the cell may be put, the electrolyte will not be spilled. Various sizes ranging from AAA, which is ½ inch in diameter and 1 inch long, to the No. 6, which is 2½ inches in diameter

and 6 inches long, are used singly and in packaged combinations wherever a dependable and easily transported source of electric power is required.

Cells are connected in series when the anode of one cell is connected to the cathode of another (Fig. 1). The combined internal resistance will be increased, and is equal to the resistance of one cell multiplied by the total number. The electromotive force of the battery will be that of one cell multiplied by the number of cells. Large combinations of dry cells forming batteries with voltages ranging up to 100 volts or more are available for special applications.

Cells are *connected in parallel* when all the anodes of a battery are connected (Fig. 2) and all the cathodes are connected together; the result is the same as if the battery were a single cell having elements of the same area as that of the combined anodes and the combined cathodes. As the resistance of a cell varies inversely as the area of the electrodes, the resistance of the battery will be that of one cell divided by the number of cells, but the electromotive force will not be increased. See also Storage Batteries.



Batteries Connected in Series and in Parallel

Battery Reading. The condition of storage battery cells during charging or discharging, may be determined either by the specific gravity method, using a hydrometer, or by the voltage method in which the voltage of the cells is determined. The specific gravity method is superior to the voltage method, as the voltages denoting various conditions of the cell vary with the current as well as with the temperature, age, and condition of the plates.

Baume Hydrometer. The Baume hydrometer is an instrument used for determining the specific gravity of liquids. It consists of a glass tube with a bulb at one end, containing air, and having a weight at the bottom, so that it will float in an upright position in the liquid, the density of which is to be measured. The depth to which the instrument sinks in the liquid is read off on a graduated scale which indicates the specific gravity.

Baumgartel Metal. Baumgartel metal is an alloy in the Britannia-metal class, composed chiefly of tin and antimony, the composition, according to one analysis, being 81.9 per cent of tin; 16.3 per cent of antimony; and 1.8 per cent of copper.

Bauxite. Bauxite is a soft clay-like substance, and, chemically, is the purest naturally occurring amorphous oxide of aluminum known. It contains large percentages of alumina (from 33 to 77 per cent), the chief value of which is that it is the main source of metallic aluminum. The material is first purified by chemical processes, after which the aluminum hydroxide is reduced in the electric furnace. Besides its use in the aluminum industry, it is used for the manufacture of artificial abrasives, firebrick and crucibles because of the refractory qualities of alumina. This mineral was originally found at Baux, France, from which it derives its name. The best bauxite mines in the world are those in the southern part of the United States.

Bayer Process. The Bayer Process is a method of producing pure alumina from bauxite. In this process, aluminate of soda ($Na_2Al_2O_4$) is formed by dissolving the alumina in the bauxite directly in a caustic-soda solution. The bauxite is first ground to about ¼-inch size pieces, then calcined or roasted to drive off the water, and after the calcined material has cooled, it is finely ground and then introduced into a 40 per cent caustic-soda solution contained in a large vessel. Steam is let into a jacket around the vessel for heating the solution, and the operation is continued for about three or four hours. About 96 per cent of the alumina content of the bauxite can be extracted in this way. The solution is filtered and afterward passed into another cylindrical vessel through which passes a shaft with paddles for stirring the liquid. In this vessel, the solution is heated for about 36 hours, at which time about 70 per cent of the alumina in solution will precipitate as hydroxide ($Al(OH)_3$). A small amount of hydroxide is usually added to the solution at the beginning of the process of precipitation, in order to start the reaction. The solution carrying the precipitated hydroxide is filtered under pressure. The filter cakes are dried in the air, calcined to drive off the remaining moisture and convert the hydroxide into oxide, and, in that way, practically pure alumina is produced.

Beam Compasses. Beam compasses, which are intended for drawing large circles or arcs, consist of a beam or strip of hard wood, carrying two heads with provision for holding a needle point and pencil-holder or pen. The head carrying the needle point is usually clamped at one end of the beam or bar, while the one carrying the pencil-holder or pen is adjusted at any point along the beam that may be required for the radius of the arc or circle to be drawn.

Beams. Parts of machines and structures subjected to bending are known mechanically as *beams;* hence, in this sense, a lever fixed at one end and subjected to a force at its other end, a rod supported at both ends and subjected to a load at its center, or the overhanging arm of a jib crane, would all be known as beams.

The stresses in a beam are principally tension and compression stresses. If a beam is supported at the ends and a load rests upon the upper side, the lower fibres will be stretched by the bending action and will be subjected to a tensile stress, while the upper fibres will be compressed and be subjected to a compressive stress. In addition to the tension and compression stresses, a loaded beam is also subjected to a stress which tends to shear it. In most cases, the shearing action can be ignored for metal beams, especially if the beams are long and the loads far from the supports. If the beams are very short and the load quite close to a support, then the shearing stress may become equal to or greater than the tension or compression stresses in the beam and in that case the beam should be calculated for shear.

Beam Formulas: In the practical application of beam formulas, there are two general classes of problems: (1) To determine the maximum safe load a given beam will support; (2) to determine the size of beam to support safely a given load. The maximum safe load for a beam of given size, shape, and material depends upon whether the load is applied at one point or along the entire span; whether the beam is supported at both ends or one end only; and also whether a beam supported at each end is held rigidly or merely rests upon the supports.

To Find Maximum Safe Load: Assume that a standard 6-inch I-beam weighing 12.5 pounds per foot rests upon supports located 8 feet 6 inches apart. This beam supports a trolley and chain hoist. Determine the maximum safe load when the trolley is midway between the supports.

A table of I-beam properties (see MACHINERY'S HANDBOOK) shows a section modulus of 7.3 for this I-beam when in its normal position.

Stress (s) at center $= \frac{Wl}{\ldots}$ and W $\quad 4Zs$

in which s = maximum fibre stress; W = load in pounds; Z = section modulus; and l = length between supports in inches. If the safe stress s is 15,000 pounds per square inch (about one-fourth the ultimate strength of structural steel), then, in this example,

$$W = \frac{4 \times 7.3 \times 15{,}000}{102} = 4300 \text{ lbs.}$$

To Find Size of Beam: If the problem is to find the size of beam for supporting a load of 4300 lbs. (see preceding example), then the formula for determining the stress at the center is transposed to find the value of Z.

$$\frac{Wl}{4s} = \frac{4300 \times 102}{4 \times 15{,}000} = 7.3$$

A table giving the section modulus of each I-beam size shows that a 6-inch I-beam weighing 12.5 lbs. per foot has a section modulus of 7.3; hence, the 6-inch size could be used.

When Beam is Fixed at Both Ends: If the 6-inch I-beam previously referred to is rigidly held or riveted at the ends instead of merely resting upon its supports, to what extent will its load capacity be increased? In this case

$$W = \frac{8Zs}{l} = \frac{8 \times 7.3 \times 15{,}000}{102} = 8600 \text{ lbs.}$$

It will be noted that the load capacity is doubled by rigid fastenings at the ends of the beam.

Beam Uniformly Loaded: A wooden beam of southern yellow pine will withstand safely a bending stress of 1300 lbs. per square inch. The length of the span is 10 feet, making l = 120 inches. Assume that the beam width b = 3 inches and the height d = 9 inches. Find the total allowable load, assuming that the load is uniformly distributed along span. For a uniform load

$$W \qquad 8Zs$$

The section modulus Z : $b \times$ $\quad \frac{3 \times}{6} = 40.5$

hence,

Bearing Metals. **The developments which have been made in the design of plain or sleeve bearings include notable ments in the characteristics of bearing materials.**

ments in the bearing alloys are not restricted to mere changes in composition but include improvements in the physical properties due to refinement in manufacture and proper application of the alloys to shells or housings. Bearing metals are usually composed of alloys of copper, lead, tin, antimony and zinc, and are known as babbitt metal, white metal, brass, phosphor-bronze, and by various trade names. The price of these bearing metals depends largely upon the constituents. Lead and zinc are cheapest, with antimony, copper, and tin increasing progressively in price in the order named, tin being the most expensive. The more lead is used in a bearing, the cheaper it will be. Lead, however, is too soft to be used alone and must be alloyed with one of the other metals. Antimony added to lead increases the hardness and brittleness; with tin added, a tougher alloy is obtained. Nearly all the various babbitt metals are alloys of lead, tin and antimony. (See Babbitt Metal.)

Bronze Bearing Metals: Plain or sleeve-type bearings made of some composition designated as "bronze" are used on many different classes of machines. The S.A.E. composition No. 64 has been widely used. This is known as phosphor bronze. It has good anti-friction qualities and stands up very well under heavy loads and severe usage. S.A.E. standard No. 660 is another alloy which has been widely used. In the automotive industry it is used for such parts as spring bushings, torque tube bushings, steering-knuckle bushings, piston-pin bushings, thrust washers, etc. S.A.E. specification No. 67 is known as a semi-plastic bronze. This is intended for use where a soft bronze with good anti-friction qualities is desired. The plasticity is of especial value when the shaft is soft and the speed high. S.A.E. alloy No. 63 is particularly adapted to bushings subject to heavy loads and severe working conditions or when there is vibration or shock. A hardened steel shaft should be used with this composition.

Porous Bronze Bearings: Bearings of this type are of bronze, but are not cast in the usual way. They are composite bearings, formed initially under heavy pressure from powdered metals and graphite. The pressed composition is subjected to a temperature high enough to convert it into a true alloy resembling cast bronze, but much more porous. This porous structure forms a reservoir for oil.

Laminated Sleeve Bearings: This thin-shell type of bearing consists of either a tin- or lead-base white metal or babbitt fused to a reinforcing back made either of steel or bronze. The steel or bronze shell provides the necessary strength. This type of bearing is used extensively in the automotive industry for connecting rods, crankshaft main bearings, camshafts, piston-pins, etc. These thin-shell bearings are not only low in cost, but efficient and per-

mit the use of a housing of smaller diameter, thus saving in material and making the assembly lighter. Moreover, these bearings are inexpensive to replace. They are used on automobile engines, aircraft engines, and for certain applications in the electrical industry. The characteristics of both the backing material and the lining may, of course, be selected to suit operating conditions. The strength of the backing material is combined with the plastic qualities of the babbitt or white-metal lining, and the degree of plasticity may be varied to suit resistance to pounding or wear. For thin linings, such as are used in aircraft engines, the S.A.E. standard babbitt composition No. 10 may be used with bronze-backed bearings, as it is very fluid. The No. 10 composition contains in percentage: Tin, 90 min.; antimony, 4 to 5; copper, 4 to 5 max.; iron, 0.08 max.; arsenic, 0.10 max.; bismuth, 0.08 max.; lead, 0.35 max.; but the lead content may be as high as 0.60 in finished steel and bronze-backed bearings if a lead-tin solder has been used in bonding the bearing metal to the backing. Bronze as a backing material is preferable to steel for certain applications. Bronze is more economical, excepting where there is large production. If there are thrust loads, the flanges of the bronze backing can carry such loads without lamination or lining. The heat conductivity of bronze is higher than that of steel. Steel, however, is preferable for bearings subjected to heavy duty as in airplane engines, steam turbines, Diesel engines, etc.

Bronze Backing Composition: The S.A.E. standard bronze backing for lined bearings contains, in percentage: Copper, 83 to 86; tin, 4½ to 6; lead, 8 to 10; zinc, 2 max.; other impurities, 0.25 max.

Bearings, Hot-Pressed. See Hot-pressed Soft-base Bearings.

Bearings, Knife-Edge. See Knife-edge Bearings.

Bearings, Oilless. See Oilless Bearings.

Bearings, Plain or Sleeve Type. In designing important main bearings, it is essential to obtain the proper relationship between the revolutions per minute, the load on the bearing and the viscosity of the lubricant. In designing a plain or sleeve bearing for a given velocity and load, the aim is to use the highest unit pressure and oil of the lowest viscosity consistent with safe operation, assuming oil-film lubrication. If the bearing area is based upon the maximum safe unit pressure, then excessive area and unnecessary friction losses will be avoided. General formulas and data applicable to the design of all classes of plain bearings cannot be given because of the many variable factors influencing the design. These factors include the lubricant and method

of applying it to the bearing, heat-radiating capacity of the bearing, finish of journal surface, properties of bearing materials, clearance, and other factors.

Critical Pressure: For a given allowable load, a certain velocity and heat-radiating capacity is necessary to maintain an oil film that will support the load. Simple empirical formulas are sometimes used to determine the "critical" or maximum pressure, but the results can only be approximate. According to one formula, the critical pressure in pounds per square inch of projected area, *below* which a perfect oil film may be maintained at a given velocity, and when using the more common grades of mineral engine oils, is approximately as follows: To find the critical pressure, divide the rubbing velocity in feet per minute by the allowable temperature, and multiply the cube root of the quotient by 140. The temperature is assumed to be 140 degrees (200 degrees max. at rubbing surface minus 60 degrees) for the more common grades of mineral engine oils.

Formula for Pressure and Velocity: In the formula $PV = R \div \mu$, if the value equivalent to $R \div \mu$ is determined for a given class of bearings, we have an approximate formula for checking allowable combinations of pressure and velocity for similar bearings and operating conditions; thus, PV is assumed to equal a constant. This constant, for a given bearing, may be determined for an allowable range of combined pressure-velocity values, without knowing what values of R and μ it represents. The value of μ covers a wide range, especially if imperfectly lubricated bearings are included; hence, the constant should be based upon the actual operation of a given type of bearing. The formula $PV =$ constant is quite generally used by manufacturers, but the constants for different types of bearings may vary from 10,000 to 350,000 or higher.

Ratio of Viscosity and Speed to Unit Pressure: If Z equals the absolute viscosity of a lubricant expressed in centipoises; N equals revolutions per minute, and P equals pressure in pounds per square inch of projected area, then the value of $ZN \div P$ for a given design of bearing and lubricant, may be used as a guide in designing similar types of bearings assuming film lubrication. To illustrate, these $ZN \div P$ values might range from, say, 10 to 100 or more, thus indicating that the $ZN \div P$ value might lie anywhere within this range provided it was far enough from the value representing the breakdown of the oil film to provide a suitable factor of safety. Close to this film-breaking-point value is the zone of minimum friction or of thin-film lubrication; hence, the $ZN \div P$ value upon which the design is based should be as close to the danger zone and to this thin-film and low-friction value as is consistent with conditions. The coefficient of friction

is assumed to be a function of these three factors when they are combined to form a single variable $ZN \div P$.

The range of $ZN \div P$ values, or the ideal one for a given bearing, can only be determined by actual tests (by combining maximum speeds with minimum loads and vice versa) because the allowable unit pressure for a given velocity and lubricant depends upon so many variable factors; moreover, these values for a given bearing in the zone representing the dividing line between stable and unstable lubrication, may change considerably as the bearing surfaces are worn smooth by running in. For example, tests on a bronze bearing resulted in a $ZN \div P$ value of 55 at the point of minimum friction or danger zone and a reduction in this value to about 5 after 75 hours running.

As the value of $ZN \div P$ decreases, the coefficient of friction decreases until the oil film begins to break down; then the frictional resistance increases as the contact with the journal is transferred from the oil film to the bearing material, the rate of increase depending upon the extent to which lubricant may remain and the frictional resistance of the bearing material itself. It is evident, then, that frictional losses are lowest when the $ZN \div P$ value is close to the value representing a change from stable to unstable lubrication.

Effect of Speed Upon Allowable Pressure: When a lubricated journal revolves, some of the lubricant will be drawn into the loaded area between the journal and bearing, thus forming a wedge-shaped oil film. This oil film will support the load on the journal within certain limits. If the velocity reaches a point where the heat is not dissipated at fast as it is generated, the viscosity of the oil may be insufficient to carry the load on the bearing; hence the maximum allowable bearing pressure per square inch depends not only upon the velocity, but also upon the viscosity of the lubricant and the rate at which heat is dissipated from the bearings either through ordinary radiation or by artificial cooling. It has been common practice to design many high-speed bearings for comparatively low unit bearing pressures; but if such bearings are rigid, have smooth accurate surfaces, and the right amount of clearance, the unit pressure (assuming perfect lubrication is maintained) may be increased as the velocity increases, up to a maximum pressure which depends upon such a complicated relationship between a number of variable factors that it can only be determined by tests with a given bearing and lubricant.

Bearing Temperatures: As a general rule, bearing temperatures should not exceed 140 to 160 degrees F. When the temperature exceeds 160 degrees F., a careful study should be made of the mechanical and lubricating conditions of the bearing.

According to the practice of the General Electric Co., bearing temperatures ordinarily are limited to 40° C. rise (104° F.) and on large machines to 30° C. rise (86° F.) When the bearing diameter or speed reaches a point at which, with air cooling, the temperatures would exceed these values, water cooling is adopted, the cooling coils usually being embedded in the babbitt. In measuring temperatures, place the thermometer in the lubricating oil if possible.

Bearing Clearance: The ratio of the clearance C (difference between journal and bearing diameters) to the diameter D is very important in connection with bearing lubrication. Accurately machined bearings with ground journals for use in steam turbines, generators, etc., usually have a clearance C equal to the amount obtained by the following formula:

$$C = D \times 0.001$$

Clearances equal to $D \times 0.0015$ and up to about $0.0035\ D$ are often used. If it is necessary to estimate the probable journal expansion, the following coefficients of expansion can be used in the absence of more specific data from the manufacturer of the material employed: Nickel steel (10 per cent nickel), 0.0000073 inch; Bessemer rolled hard steel, 0.0000056 inch; Bessemer rolled soft steel, 0.0000063 inch.

The foregoing values represent the coefficients of expansion per inch of diameter per degree F.

Diameter of Journal: It has been assumed quite generally that the journal diameter should be held down to the minimum required for strength and stiffness in order to obtain as low a rubbing velocity V in feet per minute as possible. It has also been assumed that unit pressure P should be decreased as the velocity is increased; however, it has been demonstrated in modern practice that increasing the velocity makes it possible to increase the unit pressure on well-lubricated bearings of good design and workmanship and within limits varying for different bearings. Moreover, higher unit pressure permits reducing the bearing length in proportion to the diameter, thus avoiding deflections which, in relatively long bearings, make it much more difficult to maintain a uniform and correct amount of clearance with resulting uniformity in bearing pressure over the entire area.

Ratio of Length to Diameter: The modern tendency is toward shorter and more rigid bearings, the lengths being less than the diameter for some types. The rigidity obtained with a short bearing is conducive to maintaining a uniform pressure film over the bearing area. Excessive length, especially if accompanied by too much deflection, results in a waste of power, whereas insuffi-

cient length for a given load, velocity, and lubricating condition may cause abrasion and seizure due to excessive unit pressures. Some ratios of length to diameter which have been used follow: Marine engine main bearings and crankpins, 1 to 1.5; stationary engine main journals, 1.5 to 2.5; stationary engine crankpins, 1; ordinary heavy shafting with fixed bearings, 2 to 3; ordinary shafting with self-adjusting bearings, 3 to 4.

Beaver-Tail Stop. The "beaver-tail" stop mechanism is used in conjunction with spur gearing to prevent or minimize inertia shock or impact at some point in a repeated cycle where a clutch is thrown or tools are brought into contact with each other or with the work. The name "beaver-tail" is applied to this mechanism because of the shape of the cam which forms an important part of it. The driving pinion revolves continuously, and drives its mating gear through ordinary gear teeth except when the "beaver-tail" mechanism comes into action, at which time the motion of the gear is controlled by the two rollers and the "beaver-tail" cam. If driven gear is to be stopped once during each revolution, one cam is attached to it. If two stops per revolution are required, two cams are used. The teeth of the driven gear are cut away at each stopping position, and the large developed tooth or cam takes their place.

Rollers on the driving pinion are diametrically opposite each other, and their centers are on the pitch circle of the pinion. When the beginning of the blank space on the gear reaches the pinion and during a partial revolution of the pinion, one roller moves along the "beaver-tail" cam and brings the gear to rest with a harmonic motion. The center of the roller at the point of engagement coincides with the point of tangency of the two pitch circles, so that engagement takes place without shock. The driven gear is locked during the brief dwell which occurs while the rollers are revolving about a concentric part of the cam. After the dwell, the other roller engages the cam and accelerates the gear until it has the same speed as the pinion, when the gear teeth mesh and the ordinary gear drive is resumed. Both stopping and starting are accomplished with harmonic deceleration and acceleration, so that there is no shock to the mechanism (except from possible backlash) due to the reversal of strains.

Bel. The *bel* is the fundamental division of a logarithmic scale for expressing the ratio of two amounts of power. The number of bels denoting such a ratio is the logarithm to the base 10 of this ratio. Thus, if P_1 and P_2 are two amounts of power, and N the number of bels denoting their ratio, then

$$N \qquad \frac{P_1}{\quad} \text{ bels}$$

The *decibel* is one-tenth of a bel and is commonly abbreviated as db. This unit is used extensively in the measurement of sound volume in telephone and radio transmission and reception, and in noise measurements of various kinds.

Bell and Spigot Joint. The usual term for the joint in cast-iron pipe. Each piece is made with an enlarged diameter or bell at one end into which the plain or spigot end of another piece is inserted when laying. The joint is then made tight by cement, oakum, lead, rubber, or other suitable substance, which is driven in or calked into the bell and around the spigot.

When a similar joint is made in wrought pipe by means of a cast bell (or hub), it is at times called "hub and spigot joint" (poor usage). *Matheson joint* is the name applied to a similar joint in wrought pipe which has the bell formed from the pipe. Applied to fittings or valves, the term means that one end of the run is a "bell," and the other end is a "spigot," similar to those used on regular cast-iron pipe.

Bell Center Punch. A prick or center punch which is mounted inside of a cone-shaped bell-mouthed casing. By placing the bell-mouthed casing over the end of a bar, the prick punch is automatically located at the center of a bar with fair accuracy.

Bellcrank. A bent lever having two arms at an angle to each other and pivoted at the point where the two arms join. Frequently, the two arms are at a right angle to each other.

Bell Metal. Bell metal is a bronze containing either 80 per cent of copper and 20 per cent of tin, or 78 per cent of copper and 22 per cent of tin. As the name indicates, it is used for bells. Many attempts have been made to substitute cheaper metals for the copper and especially for the large percentage of tin, but these have proved unsuccessful, because good tone values have not been obtained from alloys not composed of the metals mentioned and in the proportions given.

Belmalloy. A pearlitic malleable iron having physical properties developed by an electric melting and continuous annealing process that are similar in many respects to the properties of 0.40 per cent carbon cast steel. The tensile strength ranges from 70,000 to 80,000 pounds per square inch; yield point, from 45,000 to 50,000 pounds per square inch; and hardness, from 179 to 207 Brinell. Can be machined more easily than steel castings, although not so easily as regular malleable-iron castings. Suitable for applications where high tensile strength, considerable hardness, comparative ease of machining, and freedom from internal stresses are of particular value in castings.

Belt-Bench. A belt-bench is a device for maintaining belts at a required tension. An improved type of belt-bench consists of a 12-inch channel, 32 feet long, supported on eight cast-iron stands. One end of this bench-like structure has a drum-shaped casting fixed permanently to it. This drum forms a receptacle for a roll of belting and also acts as the equivalent of a pulley around which to lay a belt. A carriage that supports a revolving drum may be adjusted along the channel rail which is graduated for measuring the lengths of belts. The tension scales of the belt-bench consist of two pairs of clamps connected by screws that act through a pair of spring balances. One pair of clamps is stationary and the spring balances are attached to them; the other pair of clamps is attached to screws which, in turn, are connected with the spring balances and are rotated by a cross-shaft which is actuated by a hand crank. This crank is used for varying the tension, as indicated by the spring balances.

Belt Cements. Two kinds of cement are used for joining the ends or plies of leather belting to produce what is generally termed an endless belt. One kind is referred to as "regular" belting cement and the other kind as "waterproof" belting cement. Both kinds can be obtained from the leather belting manufacturer, and either has ample strength and durability. When a belt is to be used in a dry place, where it is not subjected to moisture, the regular belting cement is employed, while the waterproof cement is used in damp places and where the belt comes in contact with water.

Preparation of Belt Cement: The regular cement usually comes in cakes or lumps, which are dissolved in water in a double-jacketed glue pot. Any pot with a double-jacket—that is, with an inner and an outer vessel, so that the heat reaches the cement through the medium of hot water, and not directly from the flame, will serve the purpose, though it is better to use the Safety or Underwriter's glue pot, for in it the glue may be maintained under heat directly at the job, and without risk of causing fire.

The cement should be made hot, but it should not be permitted to boil. It should be reduced with hot water to a proper consistency to spread easily, and must be applied "piping" hot, to get the best results. It is desirable, too, that it should be applied fresh, and it is better not to attempt to use over the remains of a previous melting, if it is old and hard. The pot and the brushes must be kept clean, as the base of this cement, animal glue, is subject to putrefaction.

Waterproof Belting Cement: The waterproof cement is essentially a liquid celluloid and its application places a layer of celluloid between the two surfaces of the lap, in which the leather fibres become embedded. It is unaffected by water, in any period

of time, because both its base and its solvent are materials that are not soluble in water. It should be used on all belts that are exposed to damp conditions, or on which water may leak.

The solvent is very volatile, and highly inflammable, and it must be kept away from any open light. This cement is in a liquid form. Usually it is ready to spread, though after some spreading the remainder will grow thicker and should be reduced by the addition of solvent, which can be obtained from the same source as the cement. This cement is more like a varnish, and it is used cold.

Application of Waterproof Cement: The surface to be cemented must be thoroughly coated with the cement, well brushed into the fibres of the leather, and then permitted to dry, which, because of the volatility of the solvent, takes place rapidly. When dry, another coat is applied. This coat is spread lightly and is also permitted to dry. When the second coat is perfectly dry, the belt is ready for the third and last coat. Care must be taken to apply the cement evenly and not leave any bare spots.

On belts wider than 12 inches, it is best not to attempt to cover more than a 5-inch cross-section of the belt at one time, since the solvent evaporates very fast, and it is easier to handle a small surface. When applying the last coat, the work must be done quickly. The joint should not be hammered, but rubbed gently or placed between boards, and pressure applied with the bench screws. The joint should "set" for a couple of hours or longer before using the belt.

Belt Conveyors. Belt conveyors are used for carrying and transporting coal, sand, gravel, etc., for comparatively short distances. These conveyors combine a high carrying capacity with low power consumption. The belt on which the material is carried is sometimes flat, the material being fed to it at the center in a narrow stream, but, in most cases, the belt is made to assume the shape of a trough by means of guiding idler pulleys set at an angle with the horizontal and placed at intervals along the length of the belt. Rubber and cotton belts may be used for belt conveyors. The speed at which belt conveyors are run varies from 200 to 800 feet per minute.

Belt Creep. If the driving and the driven shafts are not parallel and the pulleys are cylindrical, the belt will creep or move toward the "low side" of the pulley or toward the side where the shafts are closer. This creeping movement is due to the fact that any given point on the edge of the belt adjacent to the low side comes into contact with the pulley before a corresponding point on the opposite side. The result is that the belt is gradually shifted over toward the low side of the pulley.

Belt Dressings. In many belt dressings a certain amount of resin is used and in almost all dressings some form of graphite. While both of these compositions possess certain adhesive qualities, in time they are sure to injure the fibre of the leather. If leather belting is properly curried, it seldom becomes hard or dry, unless it is working under adverse conditions. Under such conditions it is advisable to use as a belt-dressing tallow mixed with a certain amount of castor oil. The tallow softens the fibres of the leather and the castor oil restores, to a large extent, the adhesive qualities in the belt. Where trouble is experienced through slippage of the belt, a few drops of castor oil on the pulley where the slipping occurs will be found to give good results. The slippage of belts is generally due to the fact that frictional heat causes the grain or pulley side of the belting to become dry. Castor oil tends to soften the grain. A treatment that has proved satisfactory in maintaining a belt's gripping power consists in saturating the belt with animal grease or fish oil once a month, removing any surplus carefully. Before the grease or oil is applied the belt should be thoroughly cleaned.

Belt Drives, Quarter-Turn. When two pulleys are mounted on shafts located at right angles to each other and are connected by a belt, this is known as a *quarter-turn drive*. Such drives should be avoided, if possible, because the belt is distorted as it twists around from one pulley to another, and, moreover, the contact between the belt and the pulleys is reduced, owing to the angular position of the belt. When installing a quarter-turn drive, it is important to align the pulleys in the proper manner. A general rule for aligning pulleys connecting shafts which are not parallel is as follows: The center of the face of the *driven* pulley must be aligned with the center of that face of the *driving* pulley from which the belt leaves.

In general, a quarter-turn belt will stay on the horizontal pulley better if the horizontal pulley is used as the driver, because when it is driving, the loose or sagging strand of the belt comes on the driven pulley, which is in a vertical plane, and therefore, the belt will run true, regardless of the sag of the loose side. If the driver pulley is in a vertical position, the loose side of the belt feeds on the horizontal pulley, and the sag of this strand tends to make the belt run off the lower side of the pulley. When the load is variable, the belt has a tendency to run in a different place on the horizontal pulley for every change in load. Tightening the belt helps to overcome this trouble, which would be experienced more or less with loose belts, at long centers, or at high speeds.

A horizontal quarter-turn belt should be from 5 to 10 per cent wider than a normal belt, other conditions remaining the same.

Under most conditions, an allowance of 5 per cent would be enough, but if the drive is severe, 10 per cent would be better.

Belt Drives, Short-Center Type. When the center distance between belt-driven shafts is comparatively short, belt slippage may occur with an ordinary flat belt drive unless it is arranged to compensate for changes in belt elongation and amount of power transmitted. There are two common methods of arranging short-center drives.

Pivoted Tension Roller Drive: One method consists in applying an idler pulley or tension roller to the slack side of the belt near the smaller pulley. This idler usually is supported by a pivoted arm or frame and has an adjustable weight for varying the pressure of the idler pulley against the belt on the slack side, if this should be required. The arm or frame is pivoted either concentric or eccentric to the axis of the smaller pulley and the idler is free to swing around the pulley, thus increasing or decreasing the arc of belt contact with increasing or decreasing loads, and maintaining the same stress in the slack side regardless of belt elongation. See also Lenix Belt Drive.

Pivoted Motor Drive: With drives of this general type, the motor base consists of a fixed member and a pivoted member to which the motor is attached. The pivot is so located that any swinging movement of the pivoted member and its attached motor will either increase or decrease the center-to-center distance between the driving and driven shafts. When the motor is rotating counter-clockwise as seen from the driving end (standard direction of rotation for most motors), then any clockwise movement of the pivoted base and motor will increase the center distance and thus tighten the belt. The position of the motor on its pivoted base may be adjusted toward or away from the pivot, so that the motor weight decreases or increases the belt tension. The tension on the belt also varies automatically with the load or amount of power being transmitted. When a motor is running, there is a counter-force or reaction torque which tends to turn the motor frame in a direction opposite to the pulley rotation. This counter-force varies in proportion to the power output; consequently, the belt tension automatically increases or decreases with the load as the pivoted motor frame swings in one direction or the other as the reaction torque changes. See also Belts, V-Type.

Belt Grip and Tension. "Belt grip" and "belt tension" are two terms that are frequently confused. A belt can be made to grip a pulley effectually by increasing its tension, but this throws an undue strain on the driving shafts and often causes hot journals. On the other hand, belts that are properly treated

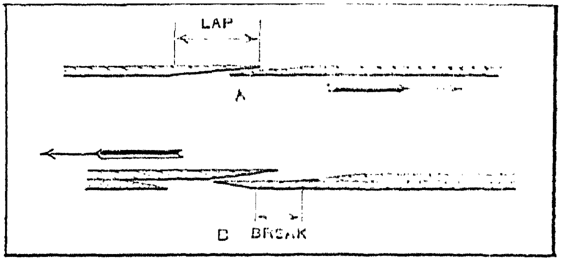
with suitable dressings can be made to grip the pulleys effectually even though running slack, assuming that there is sufficient belt length, weight and pulley contact area, which may not be the case when the center distance is comparatively short. The importance of grip as distinguished from tension cannot be too fully appreciated. Some are of the opinion that when a belt fails to transmit the required power it should have its tension increased by tightening. The effective pulling power of a belt is the difference in the tension on the slack and tight sides. It is obvious that the greater the grip of the belt on the pulley, which increases proportionally with the arc of contact, the greater power it will transmit. It follows, therefore, that a belt running slack, provided it grips the pulley effectively, will give a better grip over a greater arc of contact than a tight belt, and that at the same time the loss of power due to friction will be reduced. Some forms of belting possess less elasticity or resiliency than others and thus transmit power more by sheer weight and tension than by gripping power. The limit of the decrease of the tension value on the slack side of a belt is at that point at which the belt slips on the pulley, the maximum pulling power being attained at the moment preceding the slip. From this it follows that the value of a pliable belt lies in the fact that the tension on its slack side may be decreased to a much greater extent than is the case with a hard belt before slipping becomes evident.

Belt Installation. Whenever practicable, belts should be installed so that the slack side is above and the driving side below the pulleys. When this condition is reversed and the slack side is below, the arc of contact and consequently the driving power is materially lessened. In the case of leather belts, these should be placed on the pulleys with the hair or grain side next to the pulley rims. When installing belts, it is also important to provide the right amount of tension, assuming that a tension roller is not used. See Belt Grip and Tension. Certain kinds of belting are affected by the weather conditions, and lengthen or shorten according to the amount of moisture in the atmosphere. Belts and pulleys should be kept clean and free from accumulations of dust and grease, and particularly lubricating oils, some of which permanently injure the leather. They should be well protected against water, and even moisture, unless especially waterproofed.

Belt Joints. Leather belts usually are made endless by overlapping the wedge-shaped ends and cementing them together with belt cement. The method of overlapping depends upon the size of the belt, whether single, double, triple, or quadruple. The single-belt lap is shown at *A* in the accompanying illustration.

Both ends must be square with the side of the belt and the beveled sections are given a fine feather edge.

The length of lap for single belts is: 6 inches for belt widths up to 5 inches; 8 inches for widths from 6 to 8 inches; 12 inches for widths from 9 to 11 inches; and 14 inches for widths from 12 to 14 inches. The skived-down ends of the new lap must follow the same direction as the other laps of the belt, which should run with laps pointing as shown at *A*. A single belt is always put on with its smooth or hair side next to the pulley, the rough or flesh side being outside.



Joints of Single- and Double-ply Belts

A commonly used lap for double leather belts is shown at *B*. The "break" varies according to the width of belt, and may be made as follows: 6 inches for belt widths up to 6 inches; 8 to 12 inches for widths from 6 to 18 inches; 18 inches for widths from 20 to 24 inches; and 24 inches for widths over 24 inches. Double belts must run with the laps pointing as shown at *B;* it is immaterial which slide is put next to the pulley.

Belt Lacing. There are many ways of fastening the ends of belts together. Frequently belts are made continuous by joining the ends with a cemented lap joint. The ends of many belts, however, are held together either by lacing or by means of some special fastening device. Some of the different methods of joining belt ends by rawhide lacing are illustrated in Figs. 1 to 3 inclusive. Narrow belts, or those having little power to transmit, are often laced together as shown at *A* in Fig. 1. As will be seen, there is only one row of holes in each belt. To begin with, the ends of the belt should be trimmed square and the holes should be punched exactly opposite one another in the two ends of the belt. The lacing is usually started in the center and in such a way that the lacing will not be crossed on that side of the belt which is to run next to the pulley. The hair or grain side of the leather should always run next to the pulley, because this side is harder and tends to crack if placed on the outside. When the grainside is next to the pulley, it is compressed as it passes over the pulley, especially if the latter is of small diameter, whereas the outer side is stretched.

Procedure in Lacing: To join the belt as shown at *A*, Fig. 1, the lacing should be drawn halfway through one of the central holes, say, hole No. 1. The upper end is then started down

through hole 2 and up through hole 3, then back through hole 2, up through hole 3, and then over to hole 4. The end is then drawn up through a hole just above hole 4 where it is fastened. In order to prevent this end from being withdrawn, an incision is made halfway through the lace which is then twisted, thus forming a barb for anchoring the end. In order to lace the opposite side of the belt, the remaining half of the lace is passed up through hole 4, then over to hole 5, up through hole 6, and so on; after the lacing is completed, this end is attached below hole 1, as the illustration shows. While the lacing operation for each side has been referred to separately, it is preferable to lace both sides at the same time unless the belt is very narrow.

The method of starting the belt lacing depends upon whether the number of holes is odd or even. If the number is odd, begin as shown by the upper illustration at *C*. Both ends of the lacing are passed down through holes 3 and 8 from the grain side of the belt. Lace *a* is inserted up through hole 3, down through hole 8, up through 4, down through 9, up through 5, down through 10, up through 5, down through 10, up through 4, down through 9, and up through 3. This end of the lace is then fastened directly back of hole 3 in the usual manner. The other end *b* of the lace is inserted through hole 7, down through hole 2, and so on until it is finally brought up through hole 8 and fastened directly back of this hole. This method of lacing is, of course, the same regardless of the number of holes, provided that number is odd. When the width of the belt is such as to require an even number of holes, the lacing should be started as illustrated by the lower view at *C*. After the lace is inserted up through holes 3 and 6 from the flesh side, the end *a* is passed down through hole 7, up through hole 4, down through hole 8, up through 4, down through 8, up through 3, down through 7, up through 2, and is then fastened in an extra hole directly back of hole 2. The lacing is completed by passing end *b* down through hole 2, up through 5, down through 1, up through 5, down through 1, up through 6, down through 2, up through 7, and then fastening it directly back of hole 7.

Lacing Two Rows of Staggered Holes: Most belts are laced through two rows of staggered holes, a very common method being illustrated in Fig. 2. The lacing is first passed through the middle holes 1 and 8 of the second row, after which it is shifted until the ends are of equal length. The lacing from hole 1 is then inserted down through hole 2, up through 3, down through 4, up through 5, down through 6, up through 7, down through 6, up through 7, down through 4, up through 5, down through 2, up through 3, down through 8, and then fastened in the usual way back of hole 8. The opposite side is, of course, laced in the

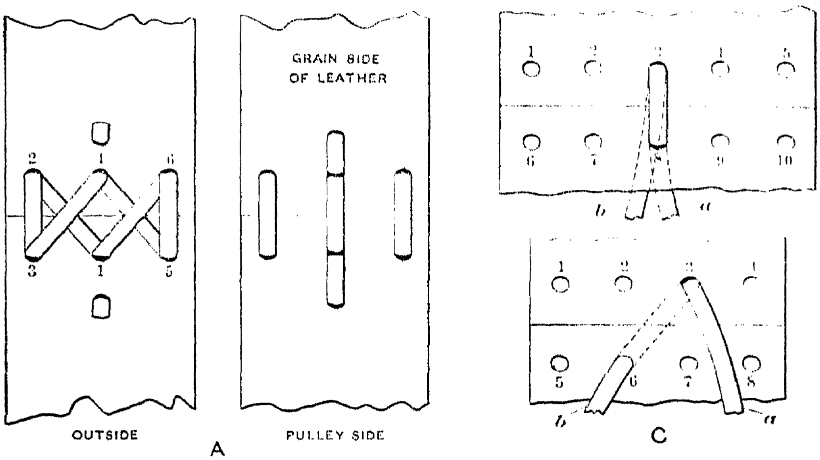


Fig. 1. The "Straight-stitch" Method of Lacing Belts

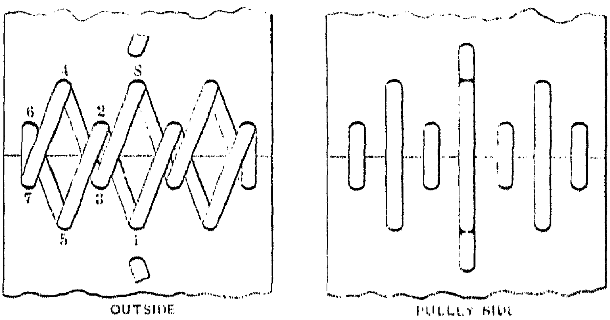


Fig. 2. Method of Lacing requiring Double Row of Holes

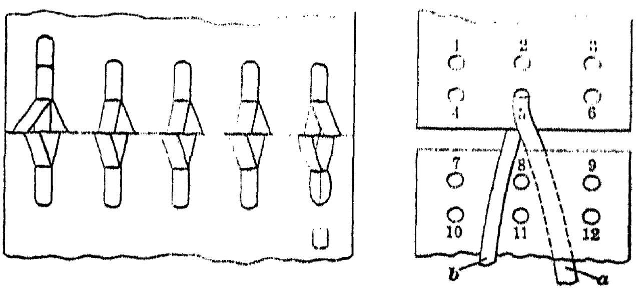


Fig. 3. Hinge-laced Joints for Belts

Belt Laces and Holes for Laced Joints

Width of Belt, Inches	Width of Lace, Inch	Number of Holes	Distance of Holes from End	
			First Row, Inches	Second Row, Inches
1–1 3/4	1/4	2 or 3	3/8	....
2–2 1/2	5/16	3	3/8	3/4
2 3/4–3 1/4	5/16	5	1/2	1
3 1/2–4 1/2	3/8	5	5/8	1 1/8
5	3/8	7	5/8	1 1/8
6	3/8	9	3/4	1 1/4
8	1/2	11	3/4	1 3/8
10	1/2	13	1	1 3/4
12	1/2	15	1	1 3/4
14	1/2	17	1 1/4	2

same manner and the end of the lace is fastened in an extra hole beyond hole 1. As previously mentioned, both sides of the belt should be laced alternately instead of lacing one side before beginning the other, especially if the belt is quite wide. The number of holes and their positions for different belt widths are given in the accompanying table.

The Hinge-laced Joint: It is desirable to so fasten the ends of a belt together that the joint is as flexible as possible, so that the joint will readily pass around a small pulley. The hinge method of lacing (illustrated in Fig. 3) is intended to give greater flexibility. Incidentally, this lacing is the same on both sides of the belt. Double rows of holes are punched in each end of the belt, the holes in the second row being exactly opposite those in the first. The holes should be at least ½ inch from the end of the belt and should be spaced about ¾ inch apart. The diameters of the holes and the widths of the laces for different widths of belts would be practically as follows: For belts up to 5 inches in width, the holes should vary from 3/16 to ¼ inch in diameter, and the width of the lace, from ¼ to 5/16 inch. A lace of light weight should also be used. For belts varying from 6 to 14 inches in width, the holes should be either 9/32, 5/16, or ⅜ inch, according to the width. The lace should be ⅜, 7/16, or ½ inch wide and of medium or heavy weight. For belts exceeding 14 inches in width, the holes should be 13/32 inch in diameter, the lace ⅝ or ¾ inch wide and of heavy stock.

In any case, the hole should be just large enough to admit the lace, to avoid weakening the belt. Frequently the lace holes are made oval by punching two holes close together. When the holes are made in this way, the oblong opening thus formed should be parallel with the edge of the belt and not the end.

To begin lacing the hinge joint, put the lace through hole 5 and draw the ends even; then place the other end of the belt between the ends of the lace, as illustrated to the right; next insert lace *a* up through hole 8, then down between the ends of the belt and up through hole 5, down through 2, up through 5 and down between the ends of the belt. Continue by inserting lace *b* down through hole 8, up through 11, down through 8, up between the belt ends, down through 4, up between the ends, down through 7, up between the ends, down through 4, up through 1, down through 4, up between the ends, down through 7, up through 10, down through 7, up between the ends, down through 4, up through 1. This end of the lace is now fastened back of hole 1. The lacing is then finished by inserting lace *a* up through hole 9, down between the belt ends, up through 6, down between the ends, up through 9, down through 12, up through 9, down between the ends, up through 6, down through 3, up through 6, down between the ends, up through 9, down through 12; this end is then fastened back of hole 12. This method of lacing may be applied to any odd number of holes, the method being to start with the center hole in every case. If the width of the belt is such as to require an even number of holes in each row, the lacing may be started in either of the two holes nearest the center.

Twisted Rawhide Belt Lacing: While the ordinary form of flat rawhide lacing has been widely used, it has two drawbacks, one of which is that the holes punched in the belt are so large that its strength is materially reduced, and the other is that the bulkiness of the lacing at the joint has a tendency to cause the belt to jerk as the joint passes over the pulley. In order to overcome these objectionable features, the twisted rawhide belt lacing may be used. This lacing consists of rawhide which is twisted into a small cord. The advantages of this method of joining a belt are: that it is only necessary to punch small holes for the lacing, so that the strength of the belt is not materially reduced; the lacing is not bulky, so that it does not interfere with the smooth running of the belt on the pulley while the lacing is in contact with it; and that the tensile strength of the lacing is relatively high. In joining a belt with this form of lacing, it is claimed that the result approaches a cemented splice as closely as it is possible for a laced joint to do. The tendency for the belt to jerk or jump when the lacing comes into contact with the

pulley is practically eliminated and this greatly reduces the strain on the belt, so that the cost of maintenance is materially reduced.

Tests on Twisted Rawhide Lacing: Tests made on belts laced with flat lacing and with twisted rawhide lacing showed the following results: A 3-inch single leather belt carefully laced with a 3/8-inch flat rawhide belt lacing showed an opening of 1/8 inch at the abutting ends when a tensile strength of 200 pounds was reached; at 760 pounds, the opening between the ends was 1/2 inch; and, when a stress of 810 pounds was reached, the belt broke at the lacing holes. A 3-inch single leather belt (taken from the same section of belting), laced with twisted rawhide lacing showed an opening of 1/16 inch at the abutting ends when a tensile stress of 900 pounds was reached; at a stress of 1460 pounds, the opening between the ends was 1/8 inch; and when a stress of 1800 pounds was reached the strands of the lacing broke. None of the lacing holes had "pulled out" or broken, and, as a matter of fact, the belt could have been relaced through the same set of holes. As there is no metal in this lacing, there is no danger of accidents from projecting ends.

Metal Belt Fasteners: A great many belts, especially of the smaller sizes, are held together by metal fastening devices which are made in many different forms. Some of these fasteners are sold in lengths which may be cut to suit the width of the belt. One common type is provided with prongs which are driven down into the belt ends and clinched, the body of the fastener extending across the joint and forming what appears to be a steel lace. Another type is composed of separate sections which have prongs that are driven into each end of the belt; the outer ends are formed somewhat like a hinge and connected by a pin which makes a flexible joint. Other fasteners are in the form of flat metal hooks that engage narrow openings in each end of the belt. There are many other types of patented fastening devices designed to provide a rapid means of joining belts and, at the same time, form joints that are strong, flexible, and smooth or even.

Belt Materials. Belts for power transmission may be made either from leather, rubber, canvas, or thin sheet steel. Leather belts are, by far, the most commonly used. Rubber belts are used when the belt is exposed to the weather conditions or to the action of steam, because they do not stretch as easily as leather belts, under these conditions. Canvas belting is used when the materials in contact with the belt and the surrounding atmosphere would affect a leather or rubber belt. Steel belts made from thin flat strips have been introduced within comparatively recent years.

Belts Made of Leather: The best grades of leather belting are made from a comparatively small section of a hide. That part of the hide extending along the spine and for some distance down the sides is firm and close in texture and the strongest for a belt. If the leather is taken too far down the side, it will be flexible and lack strength and closeness of texture. If the strips are cut too long, the ends will be taken from the neck of the animal, which is also inferior stock. A "short lap" belt is one made entirely from that part of the hide which comes from the back of the animal and the strips are not long enough to include any portion of the neck stock. The use of the poorer grades with the best grades of leather belting is particularly bad. The inferior grades soon stretch, throwing almost the entire stress of belt pull on the superior grade. This uneven tension quickly deteriorates the belt. Probably a belt made up in this manner is inferior to that made of the poorer grades throughout. Making the belt of inferior grades throughout has the merit of equalizing the stretch, keeping both parts in even tension. Oak-tanned leather is often considered the best for belting, although many high-grade belts are no longer tanned by the use of oak bark. Assuming that a good grade of leather is used, uniformity in the material is of first importance; that is, the different sections of which the belt is made should all be of the same grade. The belts should also be thoroughly stretched so that they do not have to be "taken up" every few days.

Piping Test for Belt Leather: Leather in the lower half of the hide, with its longer and looser fibres, is softer and spongier than the upper part, and the grain surface of the leather is not so firmly attached to the inner fibre; hence, in bending this leather, it will develop usually into wrinkles or "pipes" in the grain. It is possible to produce "pipes" in almost any piece of leather by bending it often enough and close enough, and applying sufficient force. A single leather belt should not show piping when bent over a form 2 inches in diameter; or a double belt when bent over a form 4 inches in diameter.

Practically all belly leather stock will show piping under this test, even when it has been rolled hard to prevent it from showing, and hence it is not desirable for belting purposes. Occasionally, pieces from the upper part of the hide will show piping under this test, but regardless of the part of the hide from which the piece is taken, the presence of piping indicates a loose grain and a flabby fibre in the leather, which is not conducive to durability in the belt, and in most cases indicates the presence of belly stock. There is another test to be applied by bending the leather over the same form, with the grain side on the outside, to detect cracking in the grain, and if this test develops a

series of minute cracks running across the width of the belt, it may be deduced that the material either is not properly tanned or is not properly curried, and that it is not suitable for good belts.

Belts Made of Fabrics: Among fabric belts (aside from rubber belts), the solid woven, impregnated cotton belt seems to take first place as a substitute for leather belts. Balata and stitched canvas belts, which are made up of plies similar to rubber belts, apparently have not been able to get a firm hold in the field of power transmission. A comparison of these types of belting shows that balata and stitched canvas belts possess a definite maximum of power transmission beyond which it is impossible to go, and that this maximum capacity is far below the capacity of leather belts. The solid-woven cotton belt seems to be the only fabric belt which nearly approaches the capacity of a leather belt. The stretch of this cotton belting in service is about the same as leather, and, like all cotton belting, it is affected by moisture and high temperature, although the effect is the reverse of the effect on leather. In damp places leather stretches and cotton shrinks; the changes in length, however, due to changes in atmospheric conditions, are much less for cotton than for leather, due to the treatment which cotton belts undergo. Although solid-woven cotton belts do not have the durability of leather belts, their flexibility is great and they can be used on the smallest pulley without much loss through bending, and without subjecting the belt to greater strain. They are unaffected by grease, grit, mineral oils, or heat.

Belt Power-Transmitting Capacity. Power ratings for belt drives vary considerably, according to different authorities and investigators, even for belts of the same kind and applied under similar conditions, as will be seen by a comparison of the conclusions found in text-books, articles, and the literature published by belt manufacturers. The general formula for determining the power rating follows:

$$II = \frac{\qquad}{33{,}000}$$

In this formula, II = horsepower; S = effective belt pull, in pounds per inch of width; V = belt velocity, in feet per minute; and W = belt width, in inches.

The effective pull or difference between the tensions on the tight and slack sides is the variable factor. This factor is affected by belt velocity and arc of pulley contact, by belt thickness and its relation to the pulley diameter, as well as the kind and quality of the belting. Even for the same belt quality, wide differences of opinion exist as to the amount of pull per unit

of width or area that is conducive to the best results when initial cost, durability, and everything pertaining to it are allowed for. If the working load is excessive, the life of belting will be reduced accordingly and the load on the bearings increased. On the other hand, if belts are given too low a rating, this means that wider and more expensive belts will be installed than is necessary. Somewhere between these extremes is the most economical rating, which is based, not only upon the initial cost of the belt but also upon all subsequent costs connected with that particular installation.

Belt Shifters. When belt-driven machine tools such as lathes, milling machines, etc., are equipped with cone pulleys, the shifting of the belt from one step of the pulley to another is somewhat dangerous when done by hand and may be quite difficult, especially when the overhead countershaft is comparatively high and the belt is under considerable tension. In order to facilitate the changing of belts on cone pulleys, mechanical shifting appliances of various kinds have been devised.

Belt Speeds. Low belt speeds are often the cause of inefficiency and waste of power. Whenever possible, belts for transmitting power should be run at from 4000 to 4500 feet per minute, while they are frequently run at only 1000 feet per minute. As a result, wide belts are being used when a narrower belt, running at a high speed, would prove both cheaper and better. In addition, bearing pressures would be lessened and the friction and accompanying wear and power consumption reduced; thus, the expense for belts, fuel, and oil would be decreased to a considerable extent.

Belts, Steel. Steel belts have been used to a very limited extent for power transmission. Their chief application at the present time is for conveyors, especially in the food industries. Steel belts may be made of hardened and tempered high-carbon steel or of stainless steel. The stainless steel has very little carbon and is used in the food industries where sanitary conditions require a stainless quality. Steel belts may range in thickness from 0.008 inch up to 0.072 inch. The pulley diameter depends upon the belt thickness and should not be less than one thousand times this thickness. For example, a belt 0.048 inch thick should be used in conjunction with a 48-inch pulley.

Belt Stretch. The stretch of a leather belt is considerably less at higher than at lower velocities. Numerous tests made with open belt drives have shown that the stretch varies from 5 per cent to 18 per cent of the belt length. While the foregoing holds true for open belt drives, quite different results have been attained with short-center belt drives. Investigations of

these belts after they had been in operation from six to ten months, showed a stretch of only 0.95 to 1.12 per cent, most of this stretch occurring during the first months of service. Thereafter no appreciable stretch took place, and the tension roller remained in its normal position. This shows that the excessive belt stretch on an open drive is due chiefly to its uncontrollable initial tension (the tension of the belt when at rest). This tension is uncontrollable because it is affected by humidity. On a short-center drive, the initial tension is eliminated almost entirely, and the stress in the slack strand of the belt is only a faction of the stress in the slack strand of an open belt drive. This is a result of the high ratio of tensions 1:5 to 1:10—according to the belt velocity—as against 1:2 on an open drive. Inasmuch as the tensions in the slack and tight strands of a belt are equal when at rest, it is reasonable to assume that the tension in the belt of a short-center drive at rest amounts to almost nothing; furthermore, the humidity has no influence on the stress of the belt, due to the tension roller. These facts account for the comparatively small stretch.

Belts, V-type. Belts of the V-type provide a compact, resilient transmission and they have been applied extensively to automotive drives for fans, generators, and water pumps, and to many miscellaneous types of machines and industrial transmissions. Only the angular sides of a V-belt should be in contact with the sides of the pulley groove. The belt is approximately flush with the top of the pulley and the pulley groove should be deep enough to provide a clearance space at the bottom of about ⅛ to 3/16 inch to insure a belt contact at the sides only. A multiple V-belt drive is commonly used instead of a single belt when required to increase the power-transmitting capacity. The driving and driven pulleys of these multiple drives are grooved for each belt, the grooves being spaced to provide clearance between the belts.

Sizes of V-belts: The five common sizes of V-belts used for miscellaneous industrial applications include both smaller and larger sizes than those in the S.A.E. standard; moreover, the widths and thicknesses of industrial V-belts differ more or less from those conforming to the S.A.E. standard. The sizes of industrial V-belts are commonly designated by the letters A, B, C, D and E, or by the use of these letters in conjunction with the belt width at the top and its thickness. The sizes follow: A, ½ by 11/32 inch; B, 21/32 by 7/16 inch; C, ⅞ by ⅝ inch; D, 1¼ by ¾ inch; E, 1½ by 1 inch. The first dimension indicates the width at the top and the last one the belt thickness.

Pulley or Sheave Groove Angles: According to the S.A.E. Standard, the included angle of the pulley groove varies from

34 to 38 degrees for different pulley diameters. The included angle of the belt itself, according to the S.A.E. specifications, is to be determined by the belt manufacturers to meet the specific requirements of each application.

Speed Ratios: Transmissions of the V-belt type commonly are applied to ratios varying from 1 to 1 up to 7½ to 1, and higher for some applications. As a general rule, the ratio should not be high enough to reduce the arc of belt contact with the smaller pulley below about 120 degrees.

Minimum Sheave Diameters: If the sheaves are too small in diameter, excessive bending of the belt will shorten its life and may result in considerable internal friction. The minimum pitch diameter of the sheave for one installation or kind of service might not be the minimum for different conditions; however, as a general rule, the minimum pitch diameters would be as follows: 3 inches for belt size A; 5.4 inches for belt size B; 9 inches for belt size C; 13 inches for belt size D; 21.6 inches for belt size E.

Center Distance between Sheaves: Belt transmissions of the vee type are particularly adapted for short-center drives, and short-center distances are recommended especially for high speeds. One rule is to make the center distance slightly larger than the diameter of the larger pulley and smaller than the sum of the diameters of both pulleys; however, both longer and shorter distances are entirely practicable. There should always be provision for a center distance adjustment not merely to compensate for any slight stretching which might occur but to facilitate installing new belts without forcing them over the sheaves. Belts of the V-type do not require initial tension. In fact, it is only necessary to adjust the center distance so as to avoid excessive slack or undue sagging of the belt.

V-Belt Speeds: The maximum speed depends upon the class of service and may be decidedly affected by the diameters of the sheaves. High speeds tend to shorten the life of the belt; on the other hand, if the speed is unnecessarily low, either a larger belt or more belts will be required for transmitting a given amount of power. In many installations, speeds should be limited to about 2500 to 3000 feet per minute, especially if the pitch diameters of the sheaves are near the minimum diameters previously given. On larger sheaves, under favorable conditions, the speeds may range from 4000 to 7000 feet per minute.

Belt Tension Scale. See Tension Scales for Belts.

Belt Thickness Specifications. The American Leather Belting Association has established specifications of thickness instead of weight, thereby discarding the old weight terminology of "ounces per square foot," which may be varied by merely adding weight-

ing materials to the leather, and does not always represent a differential in transmission values. The thickness specifications for first-quality leather belting are as follows:

Medium Single	10/64 to 12/64 inch;
Heavy Single	12/64 to 14/64 inch;
Light Double	15/64 to 17/64 inch;
Medium Double	18/64 to 20/64 inch;
Heavy Double	21/64 to 23/64 inch.

1. All thicknesses in the table are average thicknesses, in inches, and should be determined by measuring twenty coils and dividing this value by the number of coils measured. In rolls of belting containing less than twenty coils, the average thickness should be determined by measuring one-half the total number of coils and dividing this value by the number of coils measured.
2. The classification of "light single" has been eliminated entirely.
3. No point in either single or double belting shall be more than 2/64 inch thicker nor more than 2/64 inch thinner than the average thickness.
4. The second and third quality brands of each manufacturer bear the same relative thickness to the manufacturer's first quality grades as they did under the old ounces per square foot specification.

Belt Weight Per Square Foot. The weight of oak-tanned leather belting varies from 12 to 18 ounces per square foot for single belts and from 22 to 33 ounces per square foot for double belts, according to the brand and thickness. The average weight of rubber belting per square foot and ply is: 0.3699 pound for 28-ounce duck; 0.3893 pound for 32-ounce duck; and 0.4923 pound for 36-ounce duck. To find the weight per lineal foot of a rubber belt, multiply the weight per square foot and ply by the number of plies and the width of the belt, in inches, and divide by 12.

Benches. The height of work-benches usually varies from 32 to 36 inches from the floor to the top of the bench, the height depending somewhat upon the nature of the work, lighter work being done on higher benches. For general purposes, the height should be about 34 inches; the width should be about 30 inches, and the top is ordinarily composed of heavy planks, 2 or 3 inches thick, in the front, and lighter 1-inch boards in the back. The thickness of the front planks is varied in accordance with the weight of the work for which the bench is intended. Maple and ash are considered the best woods for bench planking. The preferable positions for benches, especially if used for fine accurate work, is the north side of the building, because the light on that side is more even throughout the day.

Bench Lathe. The modern bench lathe finds wide application in the manufacture of small parts requiring considerable accuracy, as well as in fine tool work, where its facility of operation and its accuracy make it an ideal tool. Bench lathes have been developed to the same high standard of efficiency as the heavier types of lathes, and the design of various attachments has broadened the field of these machines so that they are able to handle a wide range of work. In addition to their adaptation to precision turning and boring operations, bench lathes may be equipped with attachments for milling and grinding, for chasing, cutting, and milling screw threads, for turret work, filing, and a variety of other operations. Many of these attachments, such as those for milling, grinding, threading, etc., are standard equipment supplied by bench lathe manufacturers, but many special attachments are also used in connection with bench lathe practice.

Bench Lathe Milling Attachments. Bench lathes are often used for milling in connection with such operations as fluting special reamers, taps, counterbores, or other cutters, and making small punches, dies, pinions, etc. Milling attachments vary in regard to the range of adjustment and methods of applying to the machine. For instance, some have a single vertical slide with or without a swivel or angular adjustment and are mounted upon the regular compound slide in order to obtain cross and lengthwise movements. Other milling attachments are mounted directly on the bed in front of the headstock, and have their own slides, as well as swivels for angular adjustment in two planes. Another variation consists in bolting the attachment to one end of the bed, instead of locating it on the bed or slide-rest. One design is held to the right-hand end of the bed, and another to the left-hand end, the headstock in the latter case being reversed. The most common practice is to use the milling attachment for holding the work and the lathe spindle for driving the cutter, but some attachments are designed to drive the cutter, which operates upon work while it is held in the lathe spindle.

Bench Lathe Tailstocks. In bench lathe practice, the tailstock is frequently used as a means of holding and feeding various classes of tools. Tailstocks for bench lathes are made in several different forms. The type intended primarily for supporting one end of centered work is designed along the general lines of the well-known engine lathe tailstock. Then there is a lever-operated tailstock for drilling, reaming, counterboring, and similar operations. Another form is operated through a rack and pinion in conjunction with a hand-lever. The cross-slide adjustment provided in this case is useful for recessing, facing, and counterboring. The "half-open" tailstock is employed for light operations such as drilling, reaming, lapping, and the cutting of

very small threads with taps or dies, while the revolving-spindle tailstock is applied to certain drilling operations. The "sliding" or "open" tailstock is similar to the half-open design, except that it has full or complete bearings. The spindle has a knob at one end and is moved by hand the same as the spindle of a traverse grinder.

Bench Lathe Tool-Slides. For certain operations on bench lathes, it is preferable to operate the tool-slide by a hand-lever instead of using an ordinary feed-screw, on account of the more rapid movement obtained. The connection between a hand-lever and slide may be direct or through a pinion meshing with a rack attached to the slide. If the manipulation of the ordinary feed-screw is too slow and a direct-acting lever does not give quite the feeding power needed, then a hand-lever which acts through the medium of a rack and pinion is the best combination.

Bench Lathe Traverse - Spindle Grinder. The traverse-spindle grinding attachment is so named because the spindle is free to slide in its bearings, and is traversed either by means of a knob at the rear end, or by placing the belt pulley between the thumb and forefinger. Such attachments are generally used for grinding or lapping holes, but they are also very satisfactory for external grinding, particularly on short end surfaces and whenever a light sensitive control is essential. Many light drilling, reaming, and milling operations are also done with the traverse-spindle attachment which is also called a "push spindle" and a "slide-spindle" attachment.

Bendalloy. Alloy composed of bismuth, lead, tin, and cadmium, having a melting point of only 160 degrees F.—considerably less than the temperature of boiling water. Used as a filler material in tube-bending operations to prevent flattening at the bent sections. With this material as a filler, tubes having walls as thin as 0.007 inch have been bent to small radii.

Bending Brake. See Brakes for Bending.

Bending Dies. Dies of this class are designed for bending sheet metal or wire parts into various shapes which are usually irregular and are produced either by pushing the stock into cavities or depressions of corresponding shape in the die or by the action of auxiliary attachments such as slides, etc., which are operated as the punch descends. A simple form of bending die would be one having an upper part or punch shaped to correspond with a depression in the die-face; such a bending die is sometimes employed for bending flat, sheet-metal plates into an irregular shape. When the material to be bent is elastic or springy, the die must be made to allow for this, or so that the part is

bent slightly beyond the required shape or angle to compensate for the backward spring when the pressure is released. Determining this allowance is a matter of experiment.

Bending Pipes and Tubes. See Pipe Bending.

Benedict Nickel. A corrosion-resisting alloy containing from 84 to 86 per cent of copper with the remainder nickel. It is adapted for condenser, distiller, feed water heater, and evaporator tubes.

Beneficiation of Iron Ore. The term "beneficiation" is applied to those processes used for the improvement of ores which result in producing an ore which contains a greater percentage of the metal to be extracted than the original mined product. It is also applied to those methods which change the physical and sometimes the chemical properties of the ore so that it will meet the requirements for a commercial product. In the past, the term "beneficiation" has been applied to ores of precious metals only, but at the present time it is also applied to the ores of other metals, such as iron. When the process produces a richer ore, more than one ton of raw material is required to produce one ton of the beneficiated ore; for example, an ore containing 40 per cent of iron may be concentrated so that it yields an ore containing 60 per cent of iron, but it is evident that at least 1½ tons of the 40-per-cent ore must be used to produce one ton of the concentrated 60-per-cent ore. There are various methods by means of which beneficiation of iron ore may be carried out.

Bermax. An improved high-lead babbitt that is not subject to oil corrosion. It has a melting point slightly higher than that of tin-base bearing alloys, and can be cast by any method without fear of segregation. Maximum permissible unit pressure, 1800 pounds per square inch. Particularly recommended for rebabbitting steel-back or bronze-back bearings or housings of cast steel or cast bronze. Suitable for a wide range of applications in the automotive, Diesel engine, pump, and compressor fields.

Bernardos Electric Welding Process. An arc-welding method in which an electric arc is drawn between the metal to be welded. The metal forms one electrode of a circuit and a carbon electrode is manipulated by the workman. The metal is fused by the high temperature of the electric arc, and filling material is provided by a metal filling rod, the end of which is held and melted in the arc.

Beryllium. A rare metallic element also known as *glucinum,* belonging to the same group of metals as magnesium, the chemical symbol of which is Be. (When the name "glucinum" is used, the chemical symbol Gl is employed.) The metal is malleable. Its

specific gravity is 1.64, its atomic weight, 9.1, and its melting point about 1800 degrees C. (about 3275 degrees F.).

Beryllium Copper. By alloying with copper, small amounts of beryllium and nickel, an alloy is obtained having high tensile strength, high fatigue limit and hardness, and also with relatively high electrical and thermal conductivity, depending upon the heat-treatment. This alloy has many applications in the electrical and aircraft industries or wherever strength, corrosion resistance, conductivity, non-magnetic and non-sparking properties are essential. Beryllium copper is obtainable in the form of sheets or plates, strips, rods, wire, and tubes.

Composition: The patented composition follows: Beryllium, 2 to 2.25 per cent; nickel, 0.25 to 0.50 per cent; iron, usually less than 0.1 per cent; copper, remainder.

Mechanical Properties: Soft annealed beryllium copper sheet has a tensile strength of about 70,000 pounds per square inch, and this may be increased to about 175,000 by average heat-treatment. By cold-working and heat-treating, the strength may be increased to about 195,000 pounds per square inch.

The hardness of beryllium copper sheets 0.050 inch thick is about 110 Brinell for soft annealed sheets and 340 Brinell when average heat-treatment is applied. The specific gravity is 8.23. The foregoing data apply to an alloy containing 2 to 2.25 per cent beryllium.

Bessemerizing of Matte. A method of refining copper which is similar to the Bessemer process for making steel from pig iron; see *Manhes process*.

Bessemer Ore. An iron ore containing such a small percentage of phosphorus that it is suitable for making pig iron which can be converted into steel by the acid Bessemer process. Such ore must not contain more than 0.07 per cent of phosphorus.

Bessemer Pig Iron. A name applied to iron which contains so little phosphorus and sulphur that it can be used for conversion into steel by the original or acid Bessemer process (restricted to pig iron containing not more than 0.10 per cent of phosphorus).

Bessemer Process. The Bessemer process of converting iron into steel is also known both as the *pneumatic* and the *fuelless;* by this process, the carbon, silicon, and manganese of molten iron, and often the phosphorus and sulphur as well, are oxidized and removed by air forced through the metal. Hence, in the Bessemer process, the product of the blast furnace may be converted into steel, thus reducing the cost of raw material for all but the highest grade of steel. The process was invented and patented in England by Sir Henry Bessemer, in 1855.

In the Bessemer process, the impurities are removed by passing air through the molten metal in many fine streams and so rapidly that the heat produced by the oxidation of these impurities is sufficient to raise the temperature of the iron from just above the melting point of cast iron to considerably above the melting point of steel.

After the converter is charged, for which purpose it is placed in a nearly horizontal position, the blast is turned on, and then the converter is placed vertically. The blast pressure is sufficient to prevent the molten iron from passing through the tuyeres into the wind box. At first, only the nitrogen of the blast passes through the metal, as the oxygen is consumed in the oxidation of silicon and manganese; as a result, no flame appears at the mouth of the converter; but, when the silicon and manganese are nearly gone, the carbon is converted into carbon monoxide by the blast, which burns at the mouth of the vessel, producing an intensely bright flame that rapidly increases in size. When all the carbon is burned, the flame drops quite suddenly, which is a sign that the process is completed. The steel is then discharged by again placing the converter in a horizontal position and shutting off the blast.

Acid Process: The original, or acid, Bessemer process is limited to comparatively fine pig irons, because dephosphorization and desulphurization do not take place. In this process, the bottom is made by putting the hard-burned fireclay tuyeres in position and then dumping in ganister until the layer is from 26 to 30 inches thick; the usual life of this bottom is from 30 to 35 heats, although some burn out in a single heat, while others last for 50 or 60 heats.

Basic Process: The basic process makes available, for the making of steel, iron that is too high in phosphorus for the acid Bessemer process and for economical use in the ordinary basic open-hearth process. It was at first known as the *Thomas-Gilchrist process*, from its inventors S. G. Thomas and P. C. Gilchrist. It differs from the acid process in that the slag is made very basic by the addition of considerable lime, the converter lining is basic, the process is not arrested at the drop of the flame, and the oxidation of phosphorus is the source of the heat. In the basic process, the converter used is from 50 to 60 per cent larger than the acid converter for the same iron charge. Its lining is from 12 to 24 inches thick at the bottom and from 8 to 16 inches thick at the nose; its bottom is from 20 to 26 inches thick. The average life of this converter is about 100 heats.

Because of their short life, basic converters are generally installed in sets of three, so that two converters may be working

while the third is being relined. In the acid method, the blast has a pressure of from 20 to 30 pounds to the square inch and the heat is completed in from 7 to 12 minutes; in the basic process, the blast has a pressure of from 25 to 35 pounds, and the heat requires from 15 to 18 minutes. The action during the first part of the basic process is similar to that of the acid; but the latter part, known as the "afterblow," is distinctive; it is at this stage that the phosphorus is removed.

Bessemer Steel. Steel made in a Bessemer converter in which the carbon and impurities are removed from the charge of molten pig iron by blowing air up through the metal. A steel of fair quality is made by this process, which is cheap and rapid. Most steel is now made by the open-hearth process.

Bevel Gear. Bevel gearing is used for transmitting motion between two shafts located at an angle to each other (usually a right angle) and normally having center lines which intersect or lie in the same plane. By using special teeth, it is possible, as in "hypoid gears" and also "skew" bevel gearing, to have the center lines of the driving and driven gears in different planes, one shaft being offset somewhat relative to the other shaft.

When the number of teeth in two gears is the same they are called *miter gears,* the pitch cone angle of each gear being equal to 45 degrees. The term *acute angle bevel gearing* is applied when the center angle or angle between the axes of the shafts is less than 90 degrees. *Obtuse angle bevel gearing* connects shafts having a center angle greater than 90 degrees.

If the pitch cone angle of a bevel gear equals 90 degrees, the gear is known as a *crown gear,* the pitch cone in this case being a pitch plane or disk. If the pitch cone angle exceeds 90 degrees, the gear is an *internal bevel gear.* The teeth of two bevel gears in mesh converge toward a common center. This converging tooth form must be obtained in cutting the teeth by a generating process, although an approximate shape can be obtained by the formed cutter process. See also Hypoid Gears; Skew Bevel Gears; Spiral Bevel Gears.

Bevel Gear Formed Cutter. A bevel gear cutter is made thinner than a spur gear cutter because it must pass through the narrow tooth spaces at the inner ends of the teeth. For 14½-degree involute teeth, there are eight cutters numbered from one to eight for each pitch and suitable for cutting bevel gears from a 12-tooth pinion to a crown gear. The cutter to use, in any case, must not only be of the required diametral pitch but the right number in the series. The number of the cutter depends upon the number of teeth in the gear or pinion. When cutting miter gears, only one cutter is needed, but, if one gear is larger

than the other, two cutters of the same pitch but of different numbers may be required.

The number of teeth for which to select the cutter is not the actual number of teeth in the gear, but is found as follows: Divide the actual number of teeth in the gear by the cosine of the pitch-cone angle. For instance, if the bevel gear is to have 35 teeth or 12 diametral pitch and the pitch cone angle is 60 degrees, the number of teeth for which to select the cutter equals $35 \div 0.5 = 70$. Therefore, a number 2 cutter of 12 diametral pitch would be used, since this number in the series is intended for numbers of teeth from 55 to 134. Cutter number 1 is for cutting gears with number of teeth ranging from 135 to a rack; number 2 from 55 to 134; number 3 from 35 to 54; number 4 from 26 to 34; number 5 from 21 to 25; number 6 from 17 to 20; number 7 from 14 to 16; and number 8 from 12 to 13.

Bevel Gear Generating Processes. In cutting spur gears by generating methods, the rack of involute gearing is represented either directly by the cutter used, or indirectly as when a circular form of cutter is generated from the rack. The relation between a rack and spur gear is similar to that of a crown gear to a bevel gear; thus the pitch surface of a rack and also of a crown gear coincides with a plane. The teeth of a crown gear are also straight sided like those of a rack, although of converging form, and the inclination of each side corresponds to the pressure angle. The cutting tools of bevel gear generators, therefore, represent the crown gear and when a bevel gear is being cut the tooth curves are derived by imparting to the work and to the cutting tool the same relative motion that would be obtained if the gear being cut were rotating in mesh with the crown gear. In addition to this generating motion, provision must be made in a practical design of machine for giving the tool or tools a reciprocating motion for cutting, and an indexing movement to the work in order to cut equally spaced teeth around the entire gear.

The generating motion on some other machines is obtained by rolling the gear being cut, relative to the cutting tool (representing a crown gear tooth) just as though this gear were finished and rolling around a stationary crown gear. Thus all the generating motion is applied to the work; the cutting tool is simply given a reciprocating motion for planing. A common type of bevel gear generator is so designed that the generating action is applied to both the work and to the cutting tools. In this case the action is similar to that of a crown gear rotating in mesh with the gear being cut, each gear revolving about a fixed axis.

Bevel Gear Ratios. When the pressure angle of bevel gearing is 14½ degrees (the angle commonly used outside of the automotive field) the minimum numbers of teeth on the pinion, recommended for different gear ratios, are as follows: Ratios from 6 to 1 down to and including 3 to 1 should have pinions with not less than 21 teeth; for a ratio of 2 to 1, 19 teeth; for 1½ to 1, 18 teeth; for 1 to 1, 14 teeth.

Bevel Gears, Gleason System. The system of bevel gears introduced by the Gleason Works is designed to give the quietest form of tooth consistent with strength and wearing qualities. The basis of the system is in using the lowest pressure angle that can be employed without sacrificing strength by introducing excessive under-cut. The use of a low pressure angle in preference to a higher one does not reduce the effective strength to the extent ordinarily supposed, because the stronger tooth section of the higher pressure angle is offset by the greater arc of action with the lower angle. With this system the gear addendum is decreased and the pinion addendum is increased as the ratios of the numbers of teeth in the gear and pinion become greater. The system has three pressure angles of 14½, 17½, and 20 degrees for all straight-tooth bevel gears having ten or more teeth in the pinion, and one angle of 14½ degrees for spiral bevel gears, except in a few special cases. This system is applicable to any pair of generated spiral- or straight-tooth bevel gears operating at right angles, where the pinion is the driver and, in the case of straight tooth gearing, has ten teeth; spiral bevel gears having less than ten teeth are included in the system. See also Spiral Bevel Gears and Hypoid Gears.

Bichromate Cell. A primary cell or battery having a zinc anode, a carbon cathode, and an electrolyte consisting of potassium or sodium bichromate, or chromic acid, dissolved in water with the addition of a little sulphuric acid. The bichromate dissolved in the electrolyte acts as a depolarizer. The cell may be used for open or closed circuits, but the elements should be removed from the electrolyte when it is not in use. The electromotive force developed is from 1.9 to 2.1 volts.

Bicycle Origin. The bicycle was invented by Baron von Drais of Mannheim. This was exhibited in Paris in 1816. It was without pedals and was propelled by using the feet in contact with the ground to push the bicycle. In 1855 Michaux, a Frenchman, applied for the first time cranks and pedals to the axle of the drive wheel. In 1877 Rosseau of Marseille used a chain and sprocket type of drive.

Bilateral Tolerance. A bilateral tolerance is a tolerance given in two directions (plus and minus) from the basic dimension.

For examples of both bilateral and unilateral tolerances see under Tolerances.

Billet. A "billet," as the term is applied in rolling mill practice, is square or round in section and from 1½ inches in diameter or square to almost 6 inches in diameter or square. Rolling mills used to prepare the ingot for the forming mills are termed "blooming mills," "billet mills," etc.

Billet Mills. See under Rolling Mills.

Binary Alloy. An alloy containing two elements. When the term is used in regard to iron or steel, it refers to a material that has one alloying element in addition to iron. Since carbon is always present in steel, plain carbon steel is the typical binary iron alloy.

Binder. The material used for holding together the sand in a dry sand core is known as a binder. Various dry compounds made from resin, dextrine, coke dust, and pitch, as well as pastes made from flour, are used as core binders. Linseed, fish, and mineral oils, and molasses and glue dissolved in water, are also used.

Birmingham Wire Gage. The Birmingham or Stubs iron wire gage is used for seamless tubing, sheet spring steel, strip steel and to some extent for galvanized iron telegraph wire. (Stubs iron wire gage differs from Stubs steel wire gage.) The Treasury Department of the United States for many years used this gage in connection with importations of wire, and the adoption of succeeding tariff acts with provisions for the assessment of duty according to gage numbers gave legislative sanction to the gage, but, in 1914, its use by the Treasury Department was finally abandoned.

Bismuth. Bismuth is a metallic element, which occurs as pure metal in veins in gneiss or clay-slate, and is frequently found in combination with ores of silver and cobalt. It is found in Saxony and in Bohemia, and also in Cornwall, England, but it is most abundant in Bolivia, which is the chief commercial source of the metal. Bismuth is a very brittle metal with a white-crystalline fracture and a reddish-white color. One of its important qualities is that it expands on passing from the molten to the solid state, and that it retains this property in a number of alloys; hence, it is frequently used with antimony in type metals, because it fills the mold completely upon solidification. Its most important use, in fact, is in alloys with other metals, and it forms an important ingredient in many of these.

One of the so-called Britannia metals is composed of 50 per cent of antimony, 25 per cent of bismuth, and 25 per cent of tin.

A good alloy for pattern letters contains 15 per cent of antimony, 15 per cent of bismuth, and 70 per cent of lead. An important use of bismuth is in alloys requiring a low fusing point. Fifty parts of bismuth alloyed with 25 parts of lead, 12.5 parts of tin and 12.5 parts of cadmium will melt at a temperature of 149 degrees F. Bismuth added to lead hardens and toughens the latter metal. An alloy consisting of 40 per cent of bismuth and 60 per cent of lead has ten times the hardness and twenty times the tensile strength of lead. Alloys of bismuth with either lead or tin can be easily cast, and fill the molds well. Bismuth alloys have been used to some extent for fusible plugs for boilers, but it has been found that the continued action of heat changes their melting point so that they cannot be depended upon to melt at the right temperature. The U. S. Navy Department specifies pure Banca tin for fusible plugs.

The atomic weight of bismuth is 208.5 (some authorities give the value as 208.0); the chemical symbol is Bi; the specific gravity, 9.8; the weight per cubic inch, 0.354 pound; and the weight per cubic foot, 611.5 pounds. The melting point is 271 degrees C. (520 degrees F.). Its thermal conductivity is lower than that of all other metals, it being 1.8 as compared with 100 for silver; its electric conductivity is from 1.2 to 1.4 (silver = 100); its coefficient of expansion per unit length, per degree F., equals 0.00000975; its specific heat is about 0.0306; and its tensile strength about 6400 pounds per square inch. At atmospheric pressure it vaporizes at temperatures above 1100 degrees C. (2000 degrees F.), but its actual boiling point is about 1400 degrees C. (2550 degrees F.).

Bismuth Bronze. Bismuth bronze is an alloy containing 69 per cent of copper, 21 per cent of zinc, 9 per cent of nickel, and 1 per cent of bismuth, with traces of tin. This alloy may be considered as a low-grade German silver.

Bit-Brace Taps. As indicated by the name, bit-brace taps are made for use in a bit-brace, and, for this reason, are provided with a square taper shank to fit the socket or jaws of a bit-brace.

Bitumastic Enamel. Bitumastic enamel is a compound for the preservation of steel against rust in bridges, cranes, roofs, ships, and other structures of iron and steel. Bitumastic enamel was selected by the engineers of the Panama Canal out of three hundred compositions which were submitted to endurance tests, to protect the steel lock-gates and other steel structures used in connection with the canal.

Bituminous Coal. Bituminous coal, generally known as soft coal, contains from 50 to 75 per cent of carbon and a large per-

centage of volatile matter, varying from 25 to 50 per cent. The heating value per pound of combustible is from 13,500 to 15,500 B.T.U. Coal of this kind gives out large volumes of smoke, and requires special care in firing. The furnaces for burning this coal must be constructed so as to prevent smoke as far as possible. *Semi-bituminous* coal contains from 75 to 85 per cent of carbon and has a heating value of from 15,500 to 16,000 B.T.U., per pound of combustible. This coal is softer than the anthracites and has a tendency to produce more smoke, but on account of its high heating value it is one of the best coals for power plant purposes.

Bivalent. A bivalent is a term used to indicate that an atom of one element combines with two atoms of another element. It is also known as *divalent*.

Black Diamond. An inferior variety of diamond used in the industries for truing hard grinding wheels. It is more expensive than *bort*, but is more economical to use for hard wheels.

Black Lead. See Plumbago.

Black-Print. A copy of a drawing similar to a *blueprint*, except that it has black lines on a white background and, therefore, closely resembles an original drawing made with black ink on white paper. Black-prints are used when it is desired to obtain the appearance of an original drawing and when a pleasing presentation of the object represented is the primary consideration. Black-print paper, for making prints having black lines on a white background, is also known as *nigrosine* paper.

Black Putty. An acid-proof cement made by carefully mixing equal portions of well dried china-clay, gas tar, and linseed oil.

Blacksmiths' Taps. A class of taps known as "blacksmiths' taps" has a long taper thread and a very short shank, the shank being only long enough for a square and a collar to prevent the tap wrench from slipping from the square down upon the body of the tap. The taper of the thread is 3/4 inch per foot; the size by which the tap is known is measured 5/8 inch from the large end of the thread. These taps are generally made with the standard number of V-threads per inch corresponding to their nominal diameter.

Black Wash. A blackening solution containing carbon applied to large dry-sand and loam cores after baking, to prevent the core sand from burning onto the casting and to assist in parting the core from the surface of the cast iron. The black wash or blackening generally consists of a powder containing graphite or

crushed coal or coke in some form. The powder is mixed with clay water, or ordinary water, thus forming a liquid paint which can be applied to the cores with a brush.

Blades' Controlling Device. A starting device for electric motors, invented in 1888 by H. H. Blades. Motor starters of the hand-operated type are designed on the same principle as the Blades' device.

Blanc Fixe. An artificial form of *barium sulphate*, made by precipitating a barium salt by a soluble sulphate, used in the making of paints for the protection of iron and steel against corrosion.

Blanchard Lathe. The Blanchard type of lathe is named after the inventor, Thomas Blanchard, who built the first lathe of this kind in 1822. This machine is designed especially for turning wooden parts of irregular shape, and has been extensively used for turning the stocks of guns and rifles. There is a former or model which corresponds to the shape required. The former is mounted on one side of an oscillating frame which carries on the opposite side the wooden blank to be turned. The former and the blank are rotated at the same speed by gearing, and the turning is done by a rapidly revolving cutter. The cutter is mounted on a carriage and traverses along the bed; at the same time, a wheel which bears against the former or model to be reproduced also moves along with the carriage, and the contact of the model with this wheel causes the frame that supports the work to oscillate in such a way that an accurate copy of the model is turned by the revolving cutter.

Blanched Copper. Blanched copper is an alloy of copper and arsenic, containing 91 per cent of copper and 9 per cent of arsenic. It is used for clock-dials and for the scales attached to thermometers and barometers. The alloy is made by heating copper strips or chips with white arsenic in an earthenware crucible. The copper and arsenic are laid in alternate layers in the crucible, and the top is covered with common salt.

Blank. The term "blank" is commonly applied in the mechanical industries to castings, forgings, sheet-metal parts, etc., which are in a preliminary unfinished form. For example, the casting or forging of a gear, is a gear *blank* before the teeth are cut. In press work, a die cuts a flat *blank* from a sheet of stock, preparatory, in many cases, to drawing, forming or bending operations for obtaining the finished form.

Blank Diameter for Sheet-Metal Drawing. Before making a blanking or drawing die, it is necessary to determine how large the flat blank must be in order to produce a shell or cup of the

required form. If the stock did not stretch while being drawn or was not ironed out and made thinner, the diameter of the blank could be determined accurately by calculating the area of the finished article and then making the blank the corresponding area. The kind of metal to be drawn, that is, whether steel, brass, copper, aluminum, etc., and whether it is hard or soft, also affects the size of the blank to some extent.

Owing to the uncertainty of obtaining the right blank diameter by calculation, a common method of procedure, especially when constructing drawing dies for parts requiring more than one or two drawing operations, is to make the drawing part of the die first. The actual blank diameter can then be determined by repeated trials, after which the blanking part of the die may be finished. The blank diameter for a plain cylindrical shell having sharp corners can be determined approximately by the following rule: Multiply the diameter of the finished shell by the height; then multiply the product by 4 and add the result to the square of the finished shell diameter. The square root of the sum thus obtained equals the blank diameter.

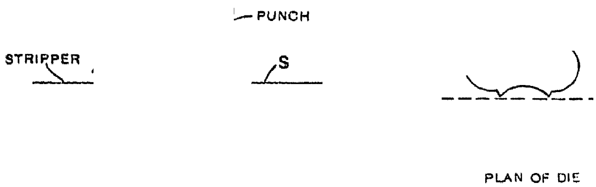
Blank-Holder. When a flat blank is drawn either in a combination or double-action die, the outer part is subjected to pressure by a blank-holder; consequently, no wrinkles can form if the die is properly constructed. After the metal has passed from under the blank-holder and over the edge of the die, it is no longer confined and, as it is being drawn into a smaller circumference, the natural tendency is to wrinkle. Such wrinkles are sometimes known as *body wrinkles* to distinguish them from the *flange wrinkles* which result when there is insufficient pressure between the blank-holder and the die.

Blanking Dies. Dies of the "blanking class" are used for cutting blanks usually from flat sheets or strips of stock; such blanks may or may not be drawn, formed or bent, either by other parts combined with the blanking members, or by means of separate dies. If the chief or only function of the die is to cut blanks, it is a blanking die; if the blanking operation is followed by a more important operation in the same die such as drawing, then the term drawing die would be applied, the blanking part being considered a secondary feature of the design.

Plain blanking dies are the simplest of all types of dies. A blanking die consists essentially of: a die-block such as *D* in the illustration which has an opening that conforms to the shape of the part to be cut or blanked out; a *punch P*, which accurately fits the opening in the die-block and, by a shearing action, does the cutting as it descends into the die-block opening; and a *stripper plate S*, which strips the stock off of the punch-block,

as the latter ascends. The opening in the stripper plate conforms to the shape of the punch and is either slightly larger to provide a little clearance, or close fitting to steady the punch. Between the stripper plate and die-block there is a *guide G*, which serves to keep the stock in alignment with the die opening as it is fed along. A most important point in making blanking dies for odd shapes is to lay them out so that the minimum amount of metal will be converted into scrap.

Blast Furnace. Blast furnaces are used for extracting the iron from iron ores; the deoxidation of the iron ore and the removal of the impurities are carried on simultaneously. Carbon, generally in the form of coke, is the deoxidizing agent, although anthracite and charcoal are also used, while limestone is added as a flux to render the slag, as the impurities are called when



Plain Blanking Punch and Die

mixed with the lime and ashes of the fuel, more fusible. The combustion of the deoxidizing agent furnishes the heat necessary to melt the resulting iron and slag. When drawn from the furnace, the iron is run into molds and cast into bars called *pigs.*

The body of a blast furnace is the preliminary heating area for the fuel and ore. It occupies by far the largest proportion of the furnace capacity, from the *bosh* at the bottom, to the *throat* at the top. Generally the sides of the body are slightly tapered, the diameter being larger at the lower end where it joins the bosh and smaller at the top where it joins the throat. The angle of inclination is usually between 3 and 8 degrees. This taper makes it easier for the charge of ore and fuel to descend in the furnace.

Blast Furnace Fuels. Charcoal was the principal blast furnace fuel for centuries, and in America it was but natural that it should be used, for timber was plentiful and much of it had

to be cut to clear the soil. Both raw coal and coke, however, had been used in Europe for smelting iron ores prior to 1651, but in this country it was not until 1855 that anthracite iron passed charcoal iron in volume of output; in 1869 bituminous fuel also passed charcoal. In 1875, bituminous fuel passed anthracite, and has now become the principal fuel. Beehive coke was used at first but this reached its maximum production in 1916, only to be passed by by-product coke in 1919.

Blast Furnace Gas. The waste gas produced by a blast furnace, containing from 20 to 26 per cent, by weight, of carbonic oxide. It is used for heating the blast, for generating steam, and for operating gas engines. Before the gas can be used in gas engines, however, it must be cooled, the dust washed out, and the gas filtered. The first large blast furnace gas engine was built in 1900. Large steel works develop thousands of horsepower from blast furnace gas.

Blast Furnace Slag. The waste material formed when converting iron ore into pig iron in the blast furnace. The slag is composed of silica, lime, and alumina, some of these ingredients originating from the ore and fuel, but most of them are from the flux used.

Bleed. A term used in foundry and blast-furnace practice to designate the condition when the metal has solidified on the surface but is not set solid on the inside, so that, if the surface is broken, the molten metal will run out, or "bleed," through the rupture.

Blind Hole. In machine construction, a hole which does not pass through a part but has a closed inner end is commonly known as a "blind hole."

Blister Copper. If metallic copper is produced in a furnace by smelting copper sulphide and copper oxide, the resulting product is known as *blister copper*. The name is derived from the fact that the escape of the sulphur dioxide in bubbles gives rise to small cavities or blisters in the mass of the copper.

Blister Steel. Blister steel is produced by the carburization of wrought iron by heating it in a furnace in contact with carbonaceous matter. It is an obsolete method, known as the *cementation process*, and was, in the early days, employed for producing tool steel. After carburizing the carburized bars, called *blister steel*, were then cut up into small pieces and remelted in a crucible, and from that poured into moulds.

Block and Tackle. "Block and tackle" is the name given to a hoisting device in which the pull on ropes passing over pulleys or sheaves lifts the load. The pulley, in its simplest form, is a

grooved wheel turning within a frame or shell to which a hook, eye, or strap is fastened. The combination of shell, pulley, and hook is known as the *block,* which, by means of the hook, or eye, may be attached to any object. The complete device usually consists of two blocks, one attached to a fixed object and the other supporting the load. The rope connecting the two blocks, and by which they are worked and the load hoisted, is known as the *tackle.* The "pulley" is one of the "mechanical powers." Combinations of pulleys and blocks are used in order to gain a mechanical advantage in raising loads.

Block Chain. A "block chain" is a type of chain especially adapted for light machine drives, formed of steel blocks connected by side links or plates. The "B-block" type is so named because the contour of the blocks resembles somewhat the letter "B." There is also what is known as the "figure-8" block which has blocks that are rounded out between the ends on both sides so that the contour resembles the figure 8. A block chain of the double width form is used when the amount of power to be transmitted is relatively high.

Block Indexing. With the multiple or "block" system of indexing, which is sometimes used in gear-cutting, a number of teeth are indexed at one time instead of cutting the teeth consecutively, and the gear is revolved several times before the teeth are all finished. For example, when cutting a gear having twenty-five teeth, the indexing mechanism is geared to index four teeth at once, and, the first time around, six widely separated tooth spaces are cut. The second time around, the cutter is one tooth behind the spaces previously milled. On the third indexing, the cutter has dropped back another tooth, and the gear is finished (in this case) by indexing it around four times. The object of this method is to distribute the heat generated by the cutter (especially when cutting cast-iron gears of coarse pitch) more evenly about the rim of the gear, thus avoiding distortion due to local heating, and permitting higher speeds and feeds.

Blood-Albumin Glue. See Glues for Wood.

Bloodstone. A natural stone of small size sometimes used for burnishing small round work in the lathe. The bloodstone is mounted in a steel holder. It is an expensive tool, but ordinarily lasts for years.

Bloom. The products of a rolling mill may be classed as semi-finished and finished. In the first class are blooms, slabs, billets, and sheet bars which have square, rhomboidal, or flat sections with rounded corners. A *bloom* has a square section and is about 6 inches square or larger.

Blooming Mill. See under Rolling Mills.

Blower. A blower may be defined as a low-pressure air compressor adapted for use in connection with forges, cupolas, gas plants, and blast furnaces. Blowers or compressors for this purpose are required to furnish air under pressures usually ranging from about two ounces to thirty pounds per square inch.

A *steel pressure fan or blower* is a special form of the ordinary ventilating fan adapted to higher pressures. The standard makes are commonly built for working pressures up to a maximum of about one pound per square inch, although special types may be constructed for considerably higher pressures. Blowers of this type are employed principally for forge and cupola practice. A *centrifugal blower* operates on the same principle as the pressure fan, but is designed for maintaining pressures up to from three to four pounds per square inch, thus considerably extending its field of operation beyond that of the steel pressure blower. A *rotary or positive pressure blower* is not a fan, although it is used for similar purposes. It is positive in its action and operates by displacement, the same as a piston compressor, although it is radically different in its construction. The maximum working pressure, with this type of blower, is limited to about ten pounds per square inch; and some of the standard makes of this type are not built for pressures exceeding five pounds per square inch. They are employed for purposes where a higher pressure is required than that which can be obtained economically by means of a centrifugal blower; but the uses to which these two types are put, overlap one another to some extent. *Rotary blowers* have a wide field of application, being used for furnishing blast for cupolas, gas and oil burners, annealing and smelting furnaces, puddle furnaces, forges, gas plants, etc., as well as for vacuum cleaning, ash conveyors, pneumatic tube service, and many other special uses. When pressures exceeding those economically produced by the centrifugal and rotary blowers are required, and, in some cases, for service for which these latter blowers could be used, the centrifugal compressor is employed, commonly known as the *turbo-compressor.*

Blower, Gas Engine. The advantage of the gas engine over steam for blower work relates chiefly to the saving in fuel gas and to the elimination of the boiler plant, in so far as it is required for this purpose alone. On the other hand, gas engines lack the flexibility of steam in case of emergencies. They have but little, if any, overload capacity, making it necessary to operate them at as nearly full load conditions as possible, and vary the power output by changing the number of units in use. Owing, however, to their greater thermal efficiency, gas engine blowers have been installed in some of the largest plants in the country.

The type commonly adopted is double-acting, having a long piston which covers the exhaust ports, which are located at the center of the cylinder, until near the end of the stroke, thus doing away with exhaust valves and simplifying the construction. Air and gas are forced into the cylinder in the right proportions by means of separate pumps.

Efficiency: The usual form of two-cycle engine has a mechanical efficiency ranging from 75 to 80 per cent, this comparatively low figure being due to the power required for operating the air and gas pumps. While the four-cycle engine has a slightly higher efficiency, it is offset to a considerable extent by the more complex valve gear.

Capacity: When supplied with blast furnace gas giving a mean effective pressure of 60 to 70 pounds per square inch, a cylinder 38 by 60 inches will develop 1000 brake horsepower at 75 to 80 revolutions per minute. Under these conditions an engine of the above dimensions could deliver approximately 20,000 cubic feet of air per minute at a pressure of 15 pounds, or 14,000 cubic feet at 25 pounds.

Blower Pressures. The pressure used in connection with blower work is of three kinds, known as *dynamic, static,* and *velocity* pressure. The dynamic pressure is that due to the momentum of the air as it leaves the fan discharge, and acts only in the direction of flow. The static pressure is that produced by placing a resistance in the path of the air current, and, when confined in a duct, causes a uniform pressure in all directions, the same as the steam pressure within a boiler. It is evident that the dynamic pressure tends to drive the air through the fan outlet, while the static pressure tends to hold it back. The difference between these is called the velocity pressure, and is the working pressure which actually forces the air through the discharge opening in the casing. The relation between the velocity pressure and the velocity of flow which it produces, for air at a temperature of 60 degrees F., is expressed very nearly by the formula:

$$v = 66\sqrt{h},$$

in which, v = velocity of flow, in feet per second; h = velocity pressure, expressed in inches of water column. Ounces per square inch may be reduced to inches of water column by multiplying by 1.73, and inches of water column may be changed to ounces per square inch by multiplying by 0.58.

Blow, Force of. See Force of Blow.

Blow-Holes in Castings. Blow-holes are the result of an outrush of gas from the core or mold materials into the molten iron, at the time of solidification. If the solidification has pro-

ceeded so far that the outrushing gas or steam cannot bubble through it and escape through the vents which should be provided for the purpose, it will be imprisoned in the casting, forming one or more holes, according to the shape of the casting and the quantity of the escaping gas. These holes may not be apparent on the outside, and quite often occur in a location where they do no particular harm, but they are frequently located at some point where they are unsightly or greatly weaken the casting.

Blowing Engine. The term "blowing engine" is commonly used to designate blowers of the piston or reciprocating type used in connection with blast furnaces. These machines are simply air compressors designed for large volumes of air at comparatively low pressures. While superseded to a certain extent by the centrifugal compressor, blowing engines are still used in some of the largest plants in the country. Both steam and gas engines are employed for driving blowers.

Blown or Thickened Oil. A class of fixed oils (usually rape or cottonseed) which are artificially thickened by forcing a current of air through them when heated. This process increases the density and viscosity. Blown oils mixed with mineral oils are very largely used as lubricants. The mineral oils used for this purpose are usually of rather low viscosity.

Blow-out Circuit-Breaker. A device for automatically opening an electric circuit, so constructed that, when it opens under load, the resulting arc is instantly extinguished as the secondary contacts are parted, due to the force of a strong magnetic field automatically set up in the iron circuit of the blow-out magnet by the current being shunted through the blow-out coils and the secondary contact when the main brush breaks contact. The secondary contacts break contact immediately afterward.

Blue Glass. Blue glass is a development of the Bureau of Standards for protecting the eyes of furnace workers. This glass provides good contrast between the appearance of the furnace walls and the melt, and yet protects the observer against the dangerous ultraviolet radiation.

Blue Metal. An impure copper sulphide, containing some iron, which is obtained when smelting copper ores. When copper and some copper oxide are present the term "purple metal" is used.

Blueprinting. Blueprinting is a process of making copies of drawings that are made on transparent paper or tracing cloth. The tracing is used in a manner similar to that of the negative in making photographic prints, except that the tracing is a

"positive," and the blueprints are negatives. The tracing with blueprint paper held tightly beneath it is exposed to the sunlight from 3 to 10 minutes, according to the intensity of light, or exposed to the brilliant electric lights in a blueprinting machine. After the exposure, the paper is washed thoroughly in cold water for about ten minutes and then hung up to dry. The print should show a deep blue color after washing and the lines should be clear white. If the color is pale blue, the print has not been exposed to the light for a sufficient length of time. If the lines of the drawing are not clear and white, the print has been over-exposed. An over-exposed blueprint can be improved upon by pouring a little of a solution made from one teaspoonful of *bichromate of potash* dissolved in one-half gallon of water, over the print while it is in the sink. The print must then be again washed with water before it is hung up to dry. The bichromate of potash solution will improve the appearance even of blueprints that have not been over-exposed.

Blueprinting Machines. When a large number of blueprints are to be made, blueprinting machines are used for making prints without the aid of sunlight. These machines are generally provided with brilliant electric light, making it possible to produce prints at any time of the day or night.

The blueprint paper with tracings on top is passed by the light at a given rate of speed, which speed may be adjusted according to the requirements. Some machines are provided with an apparatus for washing and drying the prints after exposure.

Blueprint Marking Ink. Ordinary red writing ink with a little sal soda added will give clear distinct marks on blueprints. Very little sal soda is needed. Different grades of ink require different amounts, the right mixture being determined by adding the soda, a few grains at a time, until the ink begins to spread the least bit as it dries. A bright vermillion can be produced, which has the advantage of being visible as soon as it is placed on the blueprint.

Blue Vitriol. The commercial name applied to copper sulphate.

Board Drop-Hammer. See under Drop-hammers.

Board Measure. Board measure, as employed for measuring lumber, is based on the assumption that all boards are 1 inch thick. In order to obtain the number of feet board measure, multiply the length in feet, the width in feet, and the thickness in inches. For example, a board 2 inches thick, 10 feet long, and 9 inches wide would equal $10 \times \frac{3}{4} \times 2 = 15$ feet board measure. Board measure is frequently abbreviated B.M.

Board Measure of Logs. See Doyle Rule; Moore & Beeman Rule; Scribner Rule; St. Croix Rule.

Bob-Weight. When reciprocating and revolving parts are connected and operated together, as in the case of a steam engine, only partial balance may be obtained by the use of a rotating counterbalance. In attempting to secure more perfect balance, what is known as a "bob-weight" has been used, though rarely. This bob-weight, as applied to a single-cylinder engine for the purpose of balancing the reciprocating parts, consists of another reciprocating part or weight operated by an eccentric in order to counteract the lack of balance in the reciprocating masses.

Boiler Capacity Rating. The total heat transferred through the heating surfaces per hour is a measure of a capacity of a steam boiler. A nominal horsepower rating for stationary boilers, according to general practice, is based upon the square feet of heating surface. It is assumed that 10 square feet of heating surface is equivalent to one boiler horsepower under normal conditions. A boiler horsepower has been defined as the evaporation of 34.5 pounds of water per hour from a temperature of 212 degrees F. into steam at atmosphere pressure.

Boiler Code. This term is generally understood to refer to the rules and specifications for the construction of steam boilers and other pressure vessels, adopted by the American Society of Mechanical Engineers.

Boiler Efficiency. Efficiency of a boiler, including the furnace and grate, is the ratio of the heat absorbed by the boiler per pound of fuel fired, to the heat of perfect combustion per pound of fuel. The efficiency of the boiler alone is the ratio of the heat absorbed by the boiler per pound of fuel fired, to the heat actually developed in the furnace per pound of fuel. The general commercial practice is to base efficiency upon the combined efficiency of the boiler, furnace and grate.

Boiler Feed-Water Hardness. Hardness of boiler feed water is a condition caused by the presence of the incrusting solids, such as carbonates, sulphates, chlorides, and nitrates of lime and magnesia. The degree of hardness is a measure of the quantity of incrusting solids which boiler feed waters contain per gallon. The hardness may be temporary or permanent. *Temporary* hardness is caused by carbonates, and *permanent* hardness by sulphates, chlorides, and nitrates.

Boiler Feed-Water Heating. Boiler feed water is usually heated before discharging it into the boilers for two reasons: First, to overcome the effect of a rapid cooling of the plates, which is likely to result in unequal contraction and the forma-

tion of leaks at the joints, and also because a considerable volume of cold water fed into a boiler tends to reduce the steam pressure and thus makes it necessary to force the furnace for a time after feeding. Second, because feed-water heaters are nearly always arranged to utilize the waste gases from the furnace or the exhaust steam from the engines, and thus a considerable saving in fuel may be realized by their use.

The percentage of saving in fuel by the use of a feed-water heater may be obtained approximately by dividing the total rise in temperature by 11. For example, if the water enters the heater at a temperature of 50 degrees F. and leaves it at 200 degrees F., the total rise is 200 — 50 = 150 degrees, and the percentage of saving is 150 ÷ by 11 = 13.6. The proportion of the heat in the steam generated by the boiler, which is utilized in heating the feed water, may be found as follows: If it is assumed that the water is to be raised from 50 to 210 degrees F., the heat absorbed by 1 pound will be 210 — 50 = 160 B.T.U. The latent heat of steam at atmospheric pressure is 966 B.T.U.; hence, 160 ÷ 966 of the heat in each pound of exhaust steam is utilized in heating the feed water. This proportion is approximately one-sixth.

Boiler Feed-Water Impurities. Pure water is a chemical compound made up of two parts of hydrogen and one part of oxygen, by volume, and weighs 62.4 pounds per cubic foot at a temperature of 62 degrees F. It is never found in a pure state under natural conditions, as it absorbs large quantities of various impurities in its passage through the air, and in filtering through the earth before it reaches the wells or streams from which it is drawn for use in boiler plants or for other purposes. The impurities commonly found in boiler feed water may be classed under three heads, as follows: 1. Those causing the formation of scale; these impurities include calcium carbonate, calcium sulphate, magnesium carbonate, and magnesium sulphate. 2. Those having a corrosive action, such as sulphuric acid, carbonic acid, magnesium chloride, calcium chloride, and sulphate of iron. 3. Alkaline impurities which include sodium carbonate, sodium sulphate, sodium chloride, potassium carbonate, potassium sulphate, and potassium chloride. In addition to the impurities mentioned, various substances are held in suspension, such as organic matter, mud and oil.

Boiler Feed-Water, Oil Test. In cases where the condensation from an exhaust steam heating system is returned to the boilers, it is often desirable to test the water for oil to see if the separators are working satisfactorily. In making this test, a sample of the water is cooled, and 250 cubic centimeters are placed in a separating funnel with 25 cubic centimeters of ether,

and thoroughly shaken. The funnel is then placed in an upright position and allowed to stand for fifteen or twenty minutes, after which the water is drawn off by means of the separating cock at the bottom. The ether solution floating on the water, which contains all of the oil, is placed in a porcelain dish and evaporated over a water bath heated by steam. No open flame should be allowed in the room, as the ether vapor is very inflammable. The solution evaporates quickly, leaving any oil which may be present in the bottom of the dish. It is not usually customary to measure the oil thus found, as any amount detected in this manner is undesirable.

Boiler Feed-Water Purification. The methods employed for the purification of feed water may be classed under three general heads as follows: 1. By filtering. 2. By heat. 3. By the use of chemicals. The character of the water will indicate whether one or more of these processes must be resorted to. Purification by mechanical means is employed only where the impurities are suspended in the water, as mud, sand, oil, vegetable matter, sewage, etc., and may be accomplished in three ways according to the substances present, and the available space for the apparatus. The methods commonly employed for this purpose are: Settling in large tanks; filtration; and skimming. Water from streams containing sawdust, chips, sticks, etc., requires simply a strainer over the suction pipe to the pump, if no other impurities are present.

Boiler Feed-Water Regulator. This is a device used in connection with steam boilers for automatically regulating the height of the water line. A simple device makes use of a float connected by means of levers to a pilot valve which admits steam pressure to, or exhausts it from, a diaphragm which controls the feed valve of the boiler.

Boiler Heating Surface. The *heating surface* of a boiler is commonly defined as that portion having one side of the plates or tubes exposed to the hot gases and the other in contact with the water. When computing the heating surface, it is more common to take the fire surface rather than the water surface. The capacity of a boiler depends not only upon the amount of heating surface, but on its arrangement as well.

Boiler Patch Bolt. See Patch Bolt.

Boiler Rate of Combustion. See Rate of Combustion for Boilers.

Boiler Scale. The scale or incrustation formed in a boiler may be due to the precipitation of mineral substances or by the

settling of mud or earthy matter held in suspension by the feed water. When the water is exceptionally bad, purifiers are often used, the water passing through the purifier before it enters the boiler. In this purifier, the temperature is raised until the water will no longer hold the carbonates and sulphates in solution, these being the most troublesome scale-forming substances; therefore, they are precipitated and remain in the purifier instead of being forced into the boiler. Various chemical substances are also introduced into boilers to combine with and dissolve the scale-forming material. One of the cheapest and most effective of these substances is carbonate of soda. It is effective in preventing and removing scale resulting from both the carbonate and sulphate of lime. The best method is to connect the feed pump or injector to a soda tank so that at regular intervals a supply of soda can be introduced into the boiler. The proper amount should be determined in each case by experiment, and usually varies between one and two pounds per day for an average boiler. The lowest quantity that is effective should be used; if too much soda is used, it is apt to cause *priming*. The soda does not injure the boiler unless it is impure and contains acids.

Among the many substances introduced into boilers with the object of preventing the scale from forming into a hard mass, may be mentioned kerosene oil and petroleum. The former is generally considered preferable. It is claimed by those who have used kerosene that one quart per day for each 100 horsepower is sufficient to prevent the formation of scale, even though the water is very hard and impure. Kerosene is also effective for breaking up and loosening hard scale after it has formed. The most certain and effective remedy for the removal of scale which has been deposited on a boiler is by mechanical means, although chipping and scraping off the scale is often difficult and sometimes impossible, owing to the lack of room. The best method is to prevent the formation of the hard scale, and the easiest way of removing impurities is by opening the blow-off valve occasionally. A large part of the scale is naturally carried to the coolest part of the boiler (to the mud drum, if there is one), and it may be removed by blowing off the boiler while under steam pressure. The fact that many impurities are held in suspension and float as a scum on the water for some time before settling, has led to the use of the surface blow-out apparatus.

Boilers, Fire-Tube. Boilers of the fire-tube type are so designed that the hot gases pass through the tubes which are enclosed in a shell and surrounded with water. The horizontal return tubular boiler is the most common form of fire-tube boiler, although the vertical form is sometimes used where floor space

is limited. Certain makes of internally fired boilers are also constructed with fire tubes, as are also the usual types of marine and locomotive boilers. The horizontal tubular boiler is extensively used for heating, and, to considerable extent, for power work. Some of the advantages claimed for the fire-tube type of boiler are its low first cost, large water capacity, and its simplicity of construction.

Boilers, Water-Tube. Water-tube boilers are so named because the water is inside the tubes, which are surrounded by the hot gases. This gives a more rapid circulation to the water, which increases the efficiency of the heating surface. In addition, the large amount of surface exposed directly to the fire increases the transmission of heat and prevents over-heating. The draft area, sometimes constricted in fire-tube boilers, is always ample in this form, which gives a slower movement to the gases and allows more time for the absorption of their heat by the water. Other advantages are the rapidity with which steam may be raised, owing to the water being divided into a large number of small streams which pass through the hottest part of the fire, and also the safety due to the same cause, the division of the water into small masses preventing serious results in case of rupture. Water-tube boilers are made both horizontal and vertical in form, the tubes in the former being inclined upward toward the front in order to assist in the circulation. When properly constructed, the different surfaces are easily reached for cleaning, and being made up of comparatively small parts, are easily transported and erected. The principal disadvantage is the small amount of water space, which limits the reserve capacity in case of sudden calls for steam.

Boiler Taps. A straight boiler tap is a hand tap having 12 threads per inch and it is used by railroads and locomotive builders for tapping straight holes in boiler plate.

Taper Boiler Taps: A hand tap having a ¾-inch taper per foot, 12 threads per inch. It is used by locomotive builders and railroad shops for tapping taper threaded holes in boiler plate.

Mud or Washout Taps: A hand tap having 1¼-inch taper per foot, 12 threads per inch. It is used in tapping and retapping the holes in mud drums in boiler work.

Boiling Point. The boiling point of a substance is the temperature at which it changes from a fluid to a gaseous form, under atmospheric pressure (14.7 pounds per square inch). The boiling point of water is 100 degrees C. (212 degrees F.). In order to cause the transformation from a fluid to a gaseous form, a certain amount of heat, known as the *latent heat of evaporation,* must be supplied to the liquid at the boiling point.

Bolster. Dies are usually held in position on the bed of a punch-press by means of a *bolster* or *diebed*, although large dies are often attached directly to the press bed. The principal functions of a bolster are: 1. That of supplying an adequate support for the die, and a holder to hold the die in its proper position to be engaged by the punch. 2. To furnish a means of attachment to the press. Bolsters are commonly made of cast iron, cast steel, or machine steel. Large manufacturers seem to favor the use of semi-steel castings, or machine steel, rather than cast iron, for bolsters for certain classes of heavy work.

Bolt Cutters. The machines used for cutting the threads on bolts are known as "bolt cutters." A typical design is called a *single* bolt cutter because it has one spindle. Some bolt cutters have two, three, or four spindles and are known as *double, triple,* and *quadruple* bolt cutters, respectively. The thread is cut by means of a die-head attached to and revolved by the spindle of the machine. The bolt cutters having two or more spindles are used in preference to the single-spindle type where large quantities of bolts are to be threaded constantly. These machines operate on the same general principle as the single-spindle design. The spindles are parallel and each one has an independent carriage and vise so that, while a thread is being cut on one bolt, another bolt is being inserted in or removed from the vise of another carriage.

Some bolt cutters are equipped with a lead-screw so that the carriage will have a positive feeding movement when a thread is being cut, in order to prevent inaccuracy in the pitch of the thread. When a bolt cutter does not have a lead-screw, the feeding movement of the carriage is derived from the action of the dies upon the thread being cut. This method of feeding is satisfactory when cutting such threads as the United States Standard, the V-thread, or a Whitworth thread. When cutting square threads, however, or those of special form, or when threading long work where the cumulative error becomes important, a lead-screw is necessary.

Bolt, Expansion. See Expansion Bolt.

Bolt Forging Machines. Upsetting and heading machines of modern design are divided into two general classes: stop-motion and continuous-motion headers. The stop-motion headers have the greatest range, and are primarily used for heading bolts, but are also used for all kinds of upset forgings. The continuous-motion headers are used only for heading rivets, carriage bolts, and short lengths of hexagon- and square-head machine bolts; they produce these parts at a much faster rate than is possible with a stop-motion header, but their range of work is limited.

Bolt Forging, Origin. The bolt and nut industry in America was started in a very small way in Marion, Conn., in 1818. In that year Micah Rugg, a country blacksmith, made bolts by the forging process. The first machine used for this purpose was a device known as a heading block, which was operated by a foot treadle and a connecting lever. The connecting lever held the blank while it was being driven down into the impression in the heading block by a hammer. The square iron from which the bolt was made was first rounded, so that it could be admitted into the block. At first Rugg only made bolts to order, and charged at the rate of sixteen cents apiece. This industry developed very slowly until 1839, when Rugg went into partnership with Martin Barnes; together they built the first exclusive bolt and nut factory in the United States in Marion, Conn. The bolt and nut industry was started in England in 1838 by Thomas Oliver, of Darlson, Staffordshire. His machine was built on a somewhat different plan from that of Rugg's, but no doubt was a further development of the first machine; Oliver's machine was known as the "English Oliver."

Bolt Head Standards. American Standard bolt heads are made in two series known as the Regular Series and the Heavy Series. Regular bolt heads (and nuts) are for general use. Heavy bolt heads (and nuts) are for use where a larger bearing surface is necessary, as, for example, where the clearance between the bolt and hole is larger or a greater wrench bearing surface is considered essential. In both the regular and heavy series, there are unfinished, semi-finished, and finished grades.

Regular Bolt Heads, Unfinished: The width across the flats of square and hexagon heads equals $1\frac{1}{2} \times$ bolt diameter, adjusted to sixteenths. Unfinished heads are not machined on any surface.

Regular Bolt Heads, Semi-Finished: The width across the flats of square and hexagon heads equals $1\frac{1}{2} \times$ bolt diameter, adjusted to sixteenths. Semi-finished heads are machined under the head only.

Regular Bolt Heads, Finished: The width across the flats equals $1\frac{1}{2} \times$ bolt diameter, excepting $\frac{1}{4}$- to $\frac{5}{8}$-inch sizes inclusive, which have widths across the flats equal to $1\frac{1}{2} \times$ bolt diameter $+ 1/16$ inch, adjusted in all cases to sixteenths. Finished bolt heads are machined on all surfaces. Finished bolt heads are made in hexagon form only.

Heavy Bolt Heads, Unfinished: The width across the flats of square and hexagon forms equals $1\frac{1}{2} \times$ bolt diameter $+ \frac{1}{8}$ inch, adjusted to sixteenths.

Heavy Heads, Semi-Finished: The width across flats of square and hexagon forms equals $1\frac{1}{2} \times$ bolt diameter $+ \frac{1}{8}$ inch, adjusted to sixteenths.

Heavy Bolt Heads, Finished: The width across flats equal $1\frac{1}{2} \times$ bolt diameter $+ \frac{1}{8}$ inch, adjusted to sixteenths—made in hexagon form only.

This standard was adopted by the American Standards Association in 1933. See also Nut Standardization.

Bolt Oil. This is a viscous neutral oil used for thread cutting. It has a gravity of about 30 degrees Baume and a viscosity of about 220.

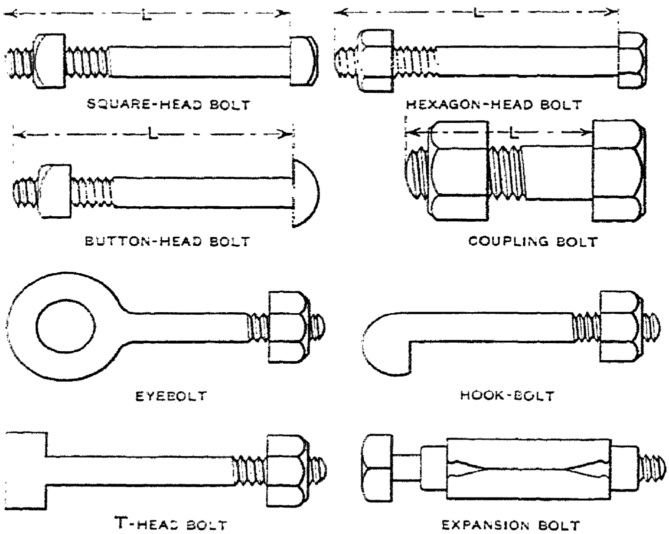
Bolt-Pointing Machines. The "bolt pointer" is a machine used for rounding or pointing the ends of bolts preparatory to cutting the thread. As the bolt leaves the "header" or machine which forms the head, the ends are generally irregular, resulting from the action of the shear in cutting the stock; this irregular edge makes it difficult to start the thread cutting die, so ordinarily a pointing tool is used which is so formed as to produce a rounding end. These pointing machines have a spindle which carries the cutter head, and a vise for holding the bolt to be pointed.

Bolts. The difference between a bolt and a screw, according to the generally accepted meaning of the terms, is that nuts are used on bolts, whereas screws are inserted into tapped holes; there are exceptions, however, to this general classification. A bolt has a solid head on one end and ordinarily one or two nuts on the other, which bind together whatever parts are to be held. A bolt may pass through a "clearance hole" or one that is slightly larger than the bolt diameter, or it may be accurately fitted to the hole so that the body of the bolt will prevent lateral movement of the parts instead of relying entirely upon the friction resulting from the pressure of the nut. The illustration shows standard bolts with the several types of heads and some special forms of bolts.

Eyebolt: The eyebolt is so named because the head forms a loop or "eye" which may be used in different ways. Eyebolts are often attached to heavy machine parts to provide means for lifting them when making repairs, etc., the eye of the bolt being engaged by the hook of a crane or hoist.

Hook-bolt: The hook-bolt is a special form of bolt having a hook-shaped head instead of one that is square or hexagonal. Such a bolt may be used when the part to be clamped is too narrow for drilling a bolt hole through it, or because such a hole would weaken the part excessively.

T-head Bolt: The T-head bolt is extensively used for clamping castings and forgings to various kinds of machine tools. The T-shaped heads of the bolts engage T-slots which extend along the table of the machine.



Standard and Special Forms of Belts

Expansion Bolt: When a through bolt cannot be used for attaching a pipe hanger, bracket, or other part, to a wall or ceiling of brick or concrete, what are known as *expansion* bolts are often used. The body of an expansion bolt is divided and the arrangement is such that, when the head of the bolt is turned, the sections forming the body of the bolt are forced outward and against the wall of the hole which has been drilled into the brick, concrete, or stone, as the case may be. Bolts of this type are made in quite a variety of designs. The nominal size represents the diameter of the bolt proper and not the diameter of the casing or expansion member.

Bolt Stresses. The initial tensional stress in a tightened bolt or stud holding a part subjected to pressure may or may not be increased by that pressure before the initial tension of the bolt is exceeded. When bolts are more elastic than the material compressed, as when flanges are bolted together without a yielding packing between, the stress in the bolts equals either the initial stress (due to tightening the nut) or the force applied, depending upon which is greater. If the material compressed is more elastic than the bolts, as when an elastic packing is compressed between flanges, the stress in the bolts equals the initial stress plus the force applied.

Bonding Processes for Grinding Wheels. By the use of different abrasives, grinding wheels can be produced which are adapted to many different purposes. The important properties of an abrasive are hardness, toughness, absence of impurities, uniformity, and fracture or sharpness. The nature or characteristics of a grinding wheel can also be changed by using different bonds, the bond being the adhesive substance which holds the abrasive grains together in the form of a wheel. The three most important bonding processes are known as the vitrified, silicate, and elastic processes, and these names are applied to the wheels. For instance, a wheel made by the vitrified process is commonly referred to as a vitrified wheel, etc. Among other processes which are occasionally employed may be mentioned the rubber or vulcanite process, the celluloid process, and the oil process.

In the *vitrified process* the abrasive is mixed with feldspar and clay; the mixture being heated to a high temperature in kilns until the clay fuses and bonds the ingredients. The wheels resulting are uniformly of open porous structure, and adapted to all kinds of general work. About 80 per cent of the wheels made are of this type.

In the *silicate process* the abrasive is mixed with silicate of soda; the mixture being subjected to a comparatively low baking temperature, around 500 degrees F., for from 20 to 80 hours. The wheels are smooth cutting and especially adapted for tools requiring a sharp edge.

In the *elastic process* the abrasive is usually bonded with shellac; the mixture being baked at a low temperature, around 300 degrees F., for a few hours. Very thin wheels can be made by this process and they are adapted for cutting off metal, tubing, wire, etc. An extremely high finish can also be obtained by the use of these wheels.

In the *rubber (vulcanite) process* the abrasive is mixed with pure rubber, to which is added sulphur as a vulcanizing agent, and heated under pressure to a temperature sufficient to vulcanize the rubber. Very thin wheels can be made by this process, and as they have a strong bond they are especially adapted for the cutting of narrow slots and grooves.

Bone Black. A material made by heating bones to a high temperature for several hours and grinding the residue. It contains a large amount of calcium phosphate and carbon, has a specific gravity of 2.68, and grinds in 50 per cent of oil. It is used for paints for the protection of iron and steel against corrosion, and to replace carbon-black and lamp black.

Bonnet. (1) A cover used to guide and enclose the tail end of a valve spindle. (2) A cap over the end of a pipe (poor usage).

Bontempi Process. A method of producing a coating on iron or steel to protect it from the corrosive effects of the atmosphere, known as the Bontempi process, consists of heating the articles with hydrogen to a low red heat in a retort, then admitting a small quantity of gasoline, and finally passing steam or fumes of zinc or of some heavy hydrocarbon, such as tar or pitch, over the articles. It is claimed that this method produces a uniform finish of dull black color which will resist corrosion for a long time.

Bonus Wage System. The task or bonus system of wage payment, introduced by H. L. Gantt, is based on the principle of increasing the pay in a certain ratio as the time of completing the job is decreased, the rate of increase in compensation depending upon the percentage of time saved. The system resembles the premium wage system very closely. Each workman always receives his regular hourly rate, a definite standard task is scientifically determined for each worker, and he receives from 50 to 100 per cent extra wages for performing this task within the time limit allowed. If he finishes the task in less than the specified time limit, he is paid his hourly pay for the time actually used for the task, as well as the bonus; he uses the time saved for a new task. The foreman is given a bonus for each man under him who earns a bonus, and receives an additional bonus if all of the men working for him earn a bonus. This stimulates the foreman to aid his men to increase the production. The method insures a definite minumum wage for unskilled labor, and a high reward for skilled and highly efficient men.

Booster. A booster is a generator inserted in series in a circuit to change its voltage. It is generally driven by an electric motor and may be either for alternating or direct current. Alternating-current boosters are mostly used in connection with synchronous-booster converters, and to a certain extent in connection with transmission systems for controlling the voltage of different plants that are operating in parallel on the same system. Direct-current boosters are used in railway power stations to raise the potential of the feeders extending to distant points of the system, and also for storage battery charging and regulation. Where there are a number of lighting feeders connected that run at full load for only a short time each day, it is generally found economical to install boosters rather than to invest in additional feeder copper. Boosters may be non-automatic or automatic in their variation of voltage. The former are used generally for charging batteries, and occasionally for assisting battery discharge, while the latter are

used for line-drop compensation and for the purpose of causing instantaneous charge and discharge of a battery on systems supplying energy to loads that fluctuate widely and rapidly in the power demand.

Booster on Locomotive. A "booster" is a supplementary engine with small cylinders applicable to the trailing wheels of any locomotive that has trailers. It is used in starting and at slow speeds, and cuts out automatically when the speed of the locomotive reaches about 15 miles an hour. Its operation is similar to the low gear of an automobile. It may be cut in at low speeds in order to get over a heavy grade which might be too steep for the main engine alone.

Boot. A bin or box built around the lower end of a bucket conveyor or elevator, into which the buckets pass and fill themselves with the material which is placed in this boot.

Borax. Sodium pyroborate and sodium biborate, a combination of sodium, boron, and oxygen, is known commercially as *borax*. The commercial use of borax is as a flux for soldering and welding. Fused borax dissolves many metallic oxides, forming with them chemical combinations. The use of borax as a flux depends upon the facts that solder adheres only to the surface of an untarnished metal, and that borax placed on the surface of the metal and heated by the soldering iron to the fusing point, removes any superficial film of oxide, and thereby makes it possible for the solder to adhere to the metal surface. Borax is obtainable in two forms: common or prismatic borax, and jewelers' or octahedral borax. The crystals of octahedral borax fuse more easily than those of the prismatic form and are, therefore, preferable to use as a flux in soldering or welding. Borax is found in large quantities in California, but the main supply is obtained from Italy.

Boring Machines. Boring machines may be divided into two general classes, *vertical* and *horizontal*. The standard designs of these machines are not intended exclusively for boring, and very often boring constitutes a small part of the work. For instance, vertical boring machines are very generally used for turning cylindrical, flat, and tapering surfaces, whereas many machines of the horizontal type may be used for drilling, milling, and flange facing. Because of this fact, the names, "vertical boring and turning machines" and "horizontal boring, drilling, and milling machines," are frequently applied to these two classes of machine tools.

Vertical Boring Machine: The vertical boring and turning machine or "mill" belongs to the lathe family, and is very efficient for work within its range. This type of machine is

designed for turning and boring work which, generally speaking, is quite large in diameter in proportion to the width or height. The part to be turned and bored is held to the machine table either by clamps or in chuck jaws attached to the table. When the machine is in operation, the table, which has a vertical spindle, revolves and the turning or boring tools remain stationary, except for the feeding movement. Very often more than one tool is used at a time.

Modern vertical boring mills of medium and large sizes are equipped with two tool-heads, because a great deal of work done on a machine of this type can have two surfaces operated upon simultaneously. On the other hand, small mills have a single head, and ordinarily the tool-slide, instead of having a single tool-block, carries a turret in which different tools can be mounted. These tools are shifted to the working position as they are needed, by indexing the turret the same as on a regular turret lathe. Frequently, all the tools for machining a part can be held in the turret, so that little time is required for changing from one tool to the next. Some large machines equipped with two tool-heads also have a turret on one head instead of the regular tool-block.

Horizontal Boring Machines: On machines of this class, the bed and cutter-driving spindle are horizontal. These machines are employed principally for boring, drilling, or milling, whereas the vertical design is especially adapted to turning and boring. The horizontal type is also used for turning or facing flanges or similar surfaces when such an operation can be performed to advantage in connection with other machine work on the same part.

The floor type of horizontal boring, drilling, and milling machine, is intended for boring heavy parts such as the cylinders of large engines or pumps, the bearings of heavy machine beds, and similar work. This machine can also be used for drilling and milling, although it is intended primarily for boring, and the other operations are usually secondary. This design is ordinarily referred to as the "floor type," because the work table is low for accommodating large heavy castings. The spindle which drives the boring-bar, and the spindle feeding mechanism, are carried by a saddle. This saddle is free to move vertically on the face of a column which is mounted on transverse ways extending across the end of the main bed. This construction permits the spindle to move vertically or laterally (by traversing the column) either for adjusting it to the required position or for milling operations. The spindle also has a longitudinal movement for boring. There is usually an outer bearing for supporting the boring-bar.

Boring Machines, Car Wheel. See Car Wheel Boring Machines.

Boring Machines, Origin. The first boring machine was built by John Wilkinson, in 1775. Smeaton had built one in 1769 which had a large rotary head, with inserted cutters, carried on the end of a light, overhanging shaft. The cylinder to be bored was fed forward against the cutter on a rude carriage, running on a track laid in the floor. The cutter head followed the inaccuracies of the bore, doing little more than to smooth out local roughness of the surface. Watt's first steam cylinders were bored on this machine and he complained that one, 18 inches in diameter, was 3/8 inch out of true. Wilkinson thought of the expedient, which had escaped both Smeaton and Watt, of extending the boring-bar completely through the cylinder and giving it an out-board bearing, at the same time making it much larger and stiffer. With this machine cylinders 57 inches in diameter were bored which were within 1/16 inch of true. Its importance can hardly be overestimated as it insured the commercial success of Watt's steam engine which, up to that time, had not passed the experimental stage.

Borite. The trade name "Borite" is used by the Vitrified Wheel Company for aluminum-oxide products. See Aluminum Oxide.

Borolon. The trade name "Borolon" is used by the Abrasive Company for aluminum-oxide products. See Aluminum Oxide.

Boron. A non-metallic chemical element, the symbol of which is B. The atomic weight of boron is 11.0; the specific gravity, 2.6; and the melting point, 2200 degrees C. (about 4000 degrees F.). It is found in nature in the form of boracic acid and in borax and boracite. It has a strong affinity for oxygen and is, therefore, one of the best deoxidizers known. For this reason it is employed when casting copper, as it is possible by its use to obtain castings which are sound, free from blow-holes, and having high electrical conductivity. See also Adamantine Boron.

Boron-Bronze. Boron-bronze is an alloy composed of aluminum and copper, with a small percentage of boron. The addition of boron increases the density of the alloy, and makes it stronger and tougher than ordinary aluminum bronze. It is probable that it is not the percentage of boron actually present in the alloy that exerts so favorable an influence; but more likely the improved qualities are due to the deoxidizing influence of boron in the molten metal.

Boronized Copper. Prior to the use of boron, it was practically impossible to cast copper of mechanical soundness and of high electrical conductivity, on account of the porous metal

that was obtained. Boron has a high affinity for oxygen, nitrogen, and oxygen-containing gases which cause the difficulty in copper casting, and since boron has no affinity for copper, it is a natural deoxidizer for copper. The boronizing process delivers a good metal, and the production of a good casting depends upon the same factors as in other metals. The boronized copper shrinks about ¼ inch to the foot. Boronized copper castings have a tensile strength of 25,000 pounds per square inch, an elastic limit of 11,500 pounds per square inch, an elongation of 48 per cent, a reduction in area of 75 per cent, and under ordinary foundry conditions an electrical conductivity of 90 (silver = 100).

Bort. Bort is an inferior variety of diamond which is used in the industries for truing soft grinding wheels and for making diamond dies for wire drawing and similar purposes. It is not as hard as the variety of diamond known as the *carbon* or *black diamond,* and is considerably lower in price; but it is not as economical to use as the black diamond for truing hard grinding wheels. While the bort is a semi-transparent stone known as an "imperfect brilliant," and, therefore, useless as a precious stone, it is very useful as an abrasive agent. It generally occurs in small spherical masses of grayish color. In its commercial usage, the term "bort" is often extended to all small and impure diamonds and crystalline fragments of diamonds which cannot be used as gems. A large proportion of these stones come from South Africa. All classes of diamonds are invariably weighed in carats and in the subdivision ½, ¼, ⅛, 1/16, 1/32 and 1/64 of a carat. 1 carat (International system) = 3.086 grains = 0.200 gram; 1 ounce troy = 155.5 carats.

Bosh. The lower melting area of a blast furnace, located just above the tuyeres is known as the "bosh." It is generally funnel-shaped, being larger at the upper end than at the lower, the walls making an angle of from 73 to 75 degrees with the horizontal, which form not only assists the blast to reach the center of the charge in the furnace, but also aids in supporting the weight of the ore and fuel.

Bower-Barff Process. This is a process for protecting iron and steel parts against the corrosive effect of air or moisture by oxidizing the surfaces. In this process, the parts to be treated are heated to a temperature of about 1650 degrees F. in a closed retort, for about forty minutes; then superheated steam is led into the retort for twenty minutes and a coating of a mixture of black and red oxides of iron is formed; producer gas is now substituted for the steam and permitted to act upon the articles for about the same length of time. If the coating

formed in this manner is not sufficiently thick, the operations may be repeated several times. Paraffin or some other oil is afterward applied to the articles. This gives them a heavy black coating, consisting essentially of magnetic oxide of iron, and gives a durable finish. A number of processes have been developed on the basis of the Bower-Barff process which differ in a number of details, but which are based on the same fundamental principle of providing a protective coating of oxide on the iron or steel.

Bow Pencil and Pen. The bow pencil is used for drawing small circles as it is a small instrument and easier to manipulate than the ordinary dividers or compass. The bow pen is of similar construction, the only difference being that it is fitted with the blades of a drawing pen instead of a socket for carrying a pencil point.

Box-Jigs. A great many parts must be drilled on different sides and, frequently, the work is very irregular in shape, so that a jig which is made somewhat in the form of a box, and encloses the work, is very essential, as it enables the guide bushings to be placed on all sides and also makes it comparatively easy to locate and securely clamp the part in the proper position for drilling. As a rule the piece to be drilled can be inserted only after one or more covers or leaves have been swung out of the way.

Box-Tools. The box-tool is a type which is equipped with some form of back-rest opposite the turning tool for supporting the work; it usually encloses or surrounds to some extent the part being turned, for which reason it is known as a *box-tool.* Tools of this type are extensively used on turret lathes and screw machines for turning parts from bar stock. There are many different designs.

Boyle's or Mariotte's Law. The volume of a gas decreases in the same ratio as the pressure upon it is increased, provided the temperature remains constant. This law is known as Boyle's or Mariotte's law. This law may also be expressed as follows: The product of the pressure times the volume is constant for constant temperatures. Hence, if $P =$ the pressure on a gas the volume of which is V, and P_1 is the pressure when the same gas occupies a volume V_1, then:

Bradley Process. A method for producing a coating on iron or steel to protect it from the corrosive effects of the atmosphere, in which the articles to be treated are heated in a retort with hydrogen gas to a low red heat, after which a small quan-

tity of gasoline is permitted to enter. The articles are then left in the furnace for an hour, or longer if the coating is not sufficiently heavy, after which they are allowed to cool, and a coating of paraffin or linseed oil applied, which gives them a fine black color and affords additional protection.

Brake Horsepower. The brake horsepower is the power of a steam engine or other power generating machine delivered from the flywheel shaft or main driving shaft of the machine. The power expended in overcoming frictional resistance in the engine itself, is not included in the brake horsepower. In order to determine the brake horsepower, a friction brake or dynamometer is applied to the rim of the flywheel, or to the shaft. The *Prony brake* is one of the simplest types of dynamometers to use for this purpose. (See also, Horsepower.)

Brakes. The purpose of a brake applied to machinery is to absorb energy by creating frictional resistance; the absorbed energy is transformed into heat, and, hence, a properly designed brake must be capable of conveying away the heat as rapidly as possible. The friction in brakes must also be distributed over a sufficiently large area to prevent undue heating of the parts in contact. Brakes with wooden friction blocks on iron drums give satisfactory service if one square inch of friction surface is allowed for each 200 or 250 foot-pounds of energy absorbed. Car brakes running with iron on iron, under conditions very favorable to quick cooling, often absorb as much as from 10,000 to 15,000 foot-pounds of energy per square inch of friction surface. Figures for other types of brakes will lie between these extremes. To facilitate radiation of heat, a ribbed exterior of the casing may be used for block brakes, and also thin ribs or vanes on the brake drum. All radiating surfaces should be left rough and black, because a finished or polished surface confines the heat instead of radiating it into the atmosphere.

Classes of Brakes: Brakes may be classified, according to their action and construction, in the following three classes:

1. Band brakes, consisting of a flexible band wrapped around the periphery of a drum.
2. Block brakes, consisting of arms carrying blocks arranged to clamp the drum between them.
3. The third class, from the method of application, should be called *axial* brakes, since they are applied in a direction parallel to the shaft; but they are often called *friction* brakes, *load* brakes, *safety* brakes, *automatic* brakes, and *mechanical* brakes. Brakes of this class are usually designed so that the retarding torque is directly proportional to the load sustained, and are largely used on electric and hand cranes for the automatic sus-

taining of the load should the power fail. The name "automatic brake" is, therefore, used for this class, although this must not be assumed to mean that either of the other two classes of brakes cannot be made to act automatically under certain conditions.

Brakes, Automatic Type. To safely hoist, hold, and lower a load, hoisting machinery is usually equipped with so-called *safety, automatic,* or *retaining* brakes. These brakes permit a load to be lifted freely by the motor, and lock the brake by the gravity of the action load as soon as the shifting torque of the motor ceases to act in the hoisting direction. The load is retained by the brake in any position, and only when the motor runs in the lowering direction is the acting power of the brake diminished, allowing the load to descend. The speed at which the load drops is regulated and determined by the lowering speed of the motor, while the brake, in the meantime, absorbs by friction the greater part of the potential energy of the dropping load, the energy absorbed by the brake is dissipated in the form of heat.

Brakes, Electric. Electric braking is extensively used for the slowing down and stopping of motors driving industrial machinery, especially hoists, cranes, etc. Such brakes are of two general classes: 1. *Solenoid-operated friction brakes,* in which the friction material is directly controlled by electric magnets for obtaining mechanical braking. 2. *Dynamic brakes,* in which the motor acts as a generator, the generating action causing the motor shaft to absorb mechanical energy from the machine to which it is connected and thereby establish a braking action. The latter method is generally supplemented by friction brakes, because the dynamic braking action ceases when the motor comes to rest, and the load may move if not held by a friction brake. See Solenoid Brake; also Dynamic Brake.

Brakes for Bending. A bending brake is a form of press used in sheet-metal work for forming strips and plates. Brakes are made in both hand-operated and power-operated types. As compared with other presses for forming sheet metals, brakes are wide between the housings and are designed for holding long, narrow forming edges or dies for giving the flat stock whatever shape is required. Brakes are used extensively in the manufacture of various kinds of metal furniture, and for miscellaneous sheet metal bending and forming operations.

Branch Pipe. This is a very general term used to signify a pipe, either cast or wrought, that is equipped with one or more branches. Such pipes are used so frequently that they have acquired common names, such as tees, crosses, side or back

outlet elbows, manifolds, double-branch elbows, etc. The term *branch pipe* is generally restricted to such as do not conform to usual dimensions.

Brasque. Brasque is a carbonaceous lining used for crucibles and furnaces. It may be composed of various carbonaceous materials, formed into a paste; the brasque of large-sized crucibles is often made from anthracite powder, powdered gas carbon, and gas-tar. The brasque of furnaces may be composed of charcoal powder, moistened and rammed in place.

Brass. Brass is an alloy composed mainly of copper and zinc and sometimes containing small percentages of lead and iron. When zinc is present in small percentages, say about 10 per cent, the color of brass is nearly red, and the alloy is known as "red brass." An alloy containing about 20 per cent of zinc is more yellow, and a number of metals with percentages of zinc around this value resemble gold, and are known as "Dutch" metal, "Mannheim gold," and various other trade names. Ordinary brass for machine construction, piping, etc., contains from 30 to 40 per cent of zinc. A number of the brasses are known by special names, such as admiralty metal, Muntz metal, manganese-bronze (which is not a bronze, but a brass composition, bronze being an alloy in which copper and tin are the basic metals), naval brass, etc.

As used in the industries, brass castings usually contain 65 per cent of copper and 35 per cent of zinc. So-called "low" brasses, which are especially suitable for hot-rolling, contain from 37 to 45 per cent of zinc. The "high" brasses, which are used for cold-rolling and drawing, contain from 30 to 40 per cent of zinc. If lead is present to an amount exceeding 0.1 per cent, the ductility of brass is decreased, and sheet brass intended for drawing should be as free from lead as possible. Brasses that must be machined, however, may contain up to 2 per cent of lead to advantage, as in that case they can be turned at high speed and a better finish obtained. Small percentages of antimony, arsenic, or bismuth in brass make it brittle and cause it to crack when rolled or drawn. In order to make brass resist the corrosion due to salt water, an addition of about 1 per cent of tin has been found advantageous.

Brass Alloys for Castings. The compositions which follow are all S.A.E. Standard and are given in percentages. Typical applications of the different alloys in the automotive industry are cited, and physical properties are given based upon standard test bars cast into sand molds and used without machining.

No. 40—Red Brass Castings: Red brass is used for water-pump impellers, fittings for gasoline and oil lines, small bush-

ings, small miscellaneous castings. This is a free-cutting brass with good casting and finishing properties.

Composition of No. 40: Copper, 84 to 86; tin, 4 to 6; lead, 4 to 6; zinc, 4 to 6; iron, max., 0.25; nickel, max., 0.75; phosphorus, max., 0.05; sulphur, max., 0.05; antimony, max., 0.25; other impurities, max., 0.15 per cent.

Physical Properties: Tensile strength, 26,000 pounds per square inch; yield point, 12,000 pounds per square inch; elongation in 2 inches (or proportionate gage length), 15 per cent.

No. 41—Yellow Brass Castings: Yellow brass is used for radiator parts, fittings for water-cooling systems, battery terminals, miscellaneous castings. This alloy is intended for commercial castings when cheapness and good machining properties are essential.

Composition of No. 41: Copper, 62 to 67; lead, 1.50 to 3.50; tin, max., 1; iron, max., 0.75; nickel, max., 0.25; phosphorus, max., 0.03; aluminum, max., 0.30; sulphur, max., 0.05; antimony, max., 0.15; other impurities, max., 0.15 per cent; zinc, remainder.

Physical Properties: Tensile strength, 20,000 pounds per square inch; elongation in 2 inches (or proportionate gage length), 15 per cent.

No. 42—White Nickel Brass Castings: This brass is used for trimmings or other parts requiring a metallic white finish. The higher the nickel content, the more permanent will be the color. Typical applications include control brackets, levers, etc., to match nickel-silver trimmings and fittings on motor-boats.

Composition of No. 42: Copper, 55 to 64; nickel, min., 18; iron, max., 0.35; other impurities, 0.25 per cent; zinc, remainder.

Physical Properties: Tensile strength, 30,000 pounds per square inch; elongation in 2 inches (or proportionate gage length), 20 per cent.

No. 44—Cast Brass to be Brazed: This brass is used for water-pipe fittings which are to be brazed. It begins to melt at about 1830 degrees F. and is entirely melted at approximately 1870 degrees F. The alloy or spelter used for brazing must have a lower melting temperature. Silver solder may be used.

Composition of No. 44: Copper, 83 to 86; zinc, 14 to 17; lead, max., 0.50; iron, max., 0.15 per cent.

Brass, Clock. See Clock Brass.

Brass Coloring. Brass and copper may be given many different colors by the use of the proper chemical solutions.

Yellow or Orange Colors: Polished brass pieces can be given a color from a golden yellow to an orange, by immersing them for the correct length of time in a solution composed of 5 parts

of caustic soda to 50 parts of water, by weight, and 10 parts of copper carbonate. When the desired shade is reached, the work must be well washed with water and dried in sawdust. Golden yellow may be produced with the following: Dissolve 100 grains of lead acetate in 1 pint of water and add a solution of sodium hydrate until the precipitate which first forms is redissolved and then add 300 grains of red potassium ferricyanide. With the solution at ordinary temperatures, the work will assume a golden yellow, but heating the solution darkens the color until, at 125 degrees F., it has changed to a brown. A pale copper color can be given brass by heating it over a charcoal fire, with no smoke, until it turns a blackish brown, then immersing in a solution of zinc chloride that is gently boiling, and finally washing thoroughly in water. Dark yellow can be obtained by immersing for five minutes in a saturated solution of common salt containing some free hydrochloric acid which has as much ammonium sulphide added as the solution will dissolve.

Rich Gold Colors: A rich gold color can be given brass by boiling it in a solution composed of 2 parts of saltpeter; 1 part of common salt; 1 part of alum; 24 parts of water, by weight; and 1 part of hydrochloric acid. Another method is to apply to the work a mixture composed of 3 parts of alum; 6 parts of saltpeter; 3 parts of sulphate of zinc; and 3 parts of common salt. The work is then heated over a hot plate until it becomes black, and then washed with water, rubbed with vinegar, and again washed and dried. Still another solution is made by dissolving 150 grains of sodium thiosulphate in 300 grains of water and adding 100 grains of an antimony-chloride solution. After boiling for some time, the red-colored precipitate must be filtered off, well washed with water, and added to 4 pints of hot water. Then add a saturated solution of sodium hydrate and heat until the precipitate is dissolved. Immerse the brass articles in the latter solution until they have attained the correct shade. If left in too long they will be given a gray color.

Black Finish on Brass: There are as many different processes and solutions for blackening brass as there are for browning, and consequently, only a few can be given. Trioxide of arsenic, white arsenic, or arsenious acid are different names for the chemical that is most commonly used. Its use can be traced back to the fifth century and it is the cheapest chemical for producing black on brass, copper, nickel, German silver, etc. It has a tendency to fade and a much greater tendency if not properly applied, but a coat of lacquer will preserve it a long time. A good black can be produced by immersing work in a solution composed of 2 ounces of white arsenic and 5 ounces of cyanide of potassium in 1 gallon of water. This should be boiled on a gas

stove, in an enamel or agate vessel, and used hot. Another cheap solution is composed of 8 ounces of sugar of lead; 8 ounces of hyposulphate of soda; and 1 gallon of water. This must also be used hot and the work afterward lacquered to prevent fading. When immersed, the brass first turns yellow, then blue, and then black, the latter being a deposit of sulphide of lead.

White Coating: The white color or coating that is given to such brass articles as pins, hooks and eyes, buttons, etc., can be produced by dipping them in a solution made up as follows: Dissolve 2 ounces of fine grain silver in nitric acid, then add 1 gallon of distilled water and put into a strong solution of sodium chloride. The silver will precipitate in the form of chloride and this must be washed until all traces of acid are removed. Testing the last rinse water with litmus paper will show when the acid has disappeared. Then mix this chloride of silver with an equal amount of potassium bitartrate (cream of tartar) and add enough water to give it the consistency of cream. The work is then immersed in this mixture and stirred around until properly coated. after which it is rinsed in hot water and dried in sawdust.

Gray Colors: A solution of 1 ounce of arsenic chloride in 1 pint of water will produce a gray color on brass, but if the work is left in too long it will turn black. The brass objects are left in the bath until they have assumed the correct shade, and then are washed in clean warm water, dried in sawdust, and finally in warm air. A dark gray color that can be made lighter by scratch-brushing can be obtained by immersing the work in the following solution: 2 ounces of white arsenic oxide; 4 ounces of commercially pure (c.p.) hydrochloric acid; 1 ounce of sulphuric acid; and 24 ounces of water. A steel gray can be produced with the following: 20 ounces of arsenious oxide; 10 ounces of powdered copper sulphate; 2 ounces of ammonium chloride; and 1 gallon of hydrochloric acid. After mixing, this should stand for one day. A 5-per-cent solution of platinum chloride in 95 per cent of water will also produce a dark gray color, if it is painted on and the brass is warmed. Weaker solutions will make the color lighter. Copper can also be colored, but the platinum does not adhere as firmly to the surface as it does on brass. A coating of lacquer is required to make it permanent. By smearing the work with a mixture of 1 part of copper sulphate and 1 part of zinc chloride in 2 parts of water, and drying this mixture on the brass, with heat, a dark brownish color is obtained. If desirous of immersing the work, a weaker solution could be used. The color is changed very little by exposure to light.

Lilac Colors: The lilac shades can be produced on yellow brass by immersing the work in the following solution when heated to between 160 and 180 degrees F. Thoroughly mix 1 ounce of

chloride, or butter, of antimony in 2 quarts of muriatic acid, and then add 1 gallon of water.

Violet Colors: A beautiful violet color can be produced on polished brass with a mixture of two solutions. First, 4 ounces of sodium hyposulphite is dissolved in 1 quart of water, then 1 ounce of sugar of lead is dissolved in another quart of water, and the two are well stirred together. By heating this mixture to 175 degrees F. and immersing the work the correct length of time, it takes on the violet color. The work first turns a golden yellow and then gradually turns to violet. If left a longer time, the violet will turn to blue and then to green. Thus, this same preparation can be used for all of these colors by correctly limiting the time that the work is immersed.

Green Colors: When left to the natural action of the atmosphere, or ageing, most of the brasses and bronzes first turn green, especially if near the ocean where the moisture from the saltwater attacks the metal. This green color gradually darkens and then turns brown, and finally black. One solution that will produce the verde antique, or rust green, is composed of 3 ounces of crystallized chloride of iron; 1 pound of ammonium chloride; 8 ounces of verdigris; 10 ounces of common salt; 4 ounces of potassium bitartrate; and 1 gallon of water. If the objects to be colored are large, this can be put on with a brush and several applications may be required to give the desired depth of color. Small work should be immersed, the length of time it is immersed governing the lightness or darkness of the color. After immersion, stippling the surface with a soft round brush, dampened with the solution, will give it the variegated appearance of the naturally aged brass or bronze. Another solution that will give practically the same results is composed of 2 ounces of ammonium chloride; 2 ounces of common salt; 4 ounces of aqua ammonia; and 1 gallon of water. The work may have to be immersed or painted several times to give it the desired coating, and, after washing and drying, it should be lacquered or waxed.

Brown Colors: Many different shades of brown can be produced and many different chemicals are used to form solutions or pastes for this purpose. In these mixtures, liver of sulphur, either potassium sulphide or sodium sulphide, is one of the most commonly used chemicals. One-fourth ounce of liver of sulphur in 1 gallon of water will give bronze a brown color, when used cold, but, if heated, it is more effective. The depth of the color is governed by the length of time that the work is immersed. If left in too long, however, it becomes black and if too much liver of sulphur is used the color will also be black. Copper is turned black even with the weak solutions. To set the color, it should afterwards be immersed in water containing a small amount of

sulphuric or nitric acid. Brass is not attacked by this solution, but if caustic potash is added it causes the liver of sulphur to color the brass. Then, 2 ounces of liver of sulphur should be added to 1 gallon of water and from 2 to 8 ounces of caustic potash, according to the shade of brown that is desired; the more potash the darker will be the color. A solution composed of ½ ounce of potassium sulphide in 1 gallon of water will produce a gray or greenish color on brass, when cold, but, when heated to 100 degrees F., it produces a light brown; at 120 degrees, a reddish brown; at 140 degrees, a dark brown; and at 180 degrees, a black color.

Bronze Color: The barbedienne bronze, or brown, color can be produced on cast brass or bronze by immersing in a solution made by dissolving 2 ounces of golden sulphuret of antimony and 8 ounces of caustic soda in 1 gallon of water. The work must be properly cleaned beforehand and afterward scratch-brushed wet, with a little pumice stone applied when brushing. It must then be well washed and dried in sawdust. A second immersion in a solution of one-half the above strength will have a toning effect, and the work must again be washed and dried. The high light can be made to show relief by rubbing the object with pumice-stone paste on a soft rag. A dead effect can be produced by immersing in a hot sulphuret of antimony solution for ten or fifteen seconds, then rewashing and immersing in hot water for a few seconds, and drying in sawdust. The work should be lacquered to preserve the tones, and waxed when the lacquer has become dry and hard. This brown color can be darkened by a five-seconds immersion in a cold solution of 8 ounces of sulphate of copper in 1 gallon of water. Some other processes use two solutions, the first of which is heated and the second used cold, after which the work is rinsed in boiling water.

Brass Cleaning Before Coloring: Cleaning brass is of the utmost importance before subjecting it to a chemical coloring process. Several acid dips will remove the films which form on brass, bronze and copper, and leave the bright clean metal with its original smooth surface. Work that will stand heating can be heated to a dull red and then plunged into dilute sulphuric acid, after which it should be soaked in old aqua fortis, and then thoroughly rinsed. It should be soaked long enough to have a uniform metallic appearance, and the bath should be large enough in volume to prevent its heating up from the hot work. The best results are obtained with straw-colored aqua fortis, as the white is too weak, and the red, too strong. In diluting the sulphuric acid, it should always be poured into the water slowly, as heat is generated, and too rapid mixing generates so much heat that the containing vessel is liable to crack and the escaping liquid

to cause burns. To pour water into sulphuric acid will cause an explosion that is almost sure to result in serious, if not fatal, burns from the flying liquid.

A good method of removing these films, without heat, is to soak the work in a "pickle" composed of spent aqua fortis until a black scale is formed, and then dip it for a few minutes into a solution composed of 64 parts of water; 64 parts of commercial sulphuric acid; 32 parts of aqua fortis; and 1 part of hydrochloric acid. After that the work should be thoroughly rinsed several times with distilled water. If the strong aqua fortis is used for the pickle in which the work is soaked, it will cause a too rapid corrosion of the copper during the time of the solution of the protoxide. Hence, the spent aqua fortis is more satisfactory on account of its slower action, and it also saves the cost of new.

Brass Colors. When brass contains 10 per cent of zinc, the mixture has a true bronze color. With 15 per cent of zinc, the brass has a light orange shade. When the amount of zinc reaches 20 per cent, the color of the mixture is greenish-yellow, and is known as "green brass." With 25 per cent of zinc, the color is practically that of the 20 per cent mixture so that this, too, is a "green brass." Brass with 30 per cent of zinc has the true, yellow brass color. The same is found with 35 per cent of zinc, but at about this point the yellow color begins to disappear, for with 40 per cent of zinc, a reddish-yellow color is found. Brass, therefore, that has a reddish-yellow shade will always contain more than 35 per cent of zinc. The "dead line" seems to be about 38 per cent of zinc, for, at this percentage, the transition from the real yellow to the reddish-yellow begins. When the zinc is increased to 45 per cent, the color of the brass is a rich golden shade and may be called "orange." The mixture containing 50 per cent of zinc has also a golden shade, but richer than the 45 per cent zinc alloy. With 55 per cent of zinc, the color resembles that of 14-carat gold. When 60 per cent of zinc is reached, the brass has a yellowish-white shade, and as the quantity increases, the color becomes white, and finally gray.

Brass Forging. Parts formed to the required shape in dies and made from forgeable brass rod are being used to replace many small castings and screw machine parts. The production of these die-formed pieces may be either by a forging or a hot-pressing process. The term "brass forging" is applied more particularly when dies are used in conjunction with some type of power hammer, such for example as a drop hammer or steam hammer. The heated brass rod is formed in dies by a succession of blows so that the operation is actually one of forging. Hot pressing, according to approved usage of the term, relates more

specifically to the use of some form of press in conjunction with suitable dies for forming heated brass slugs by a single press stroke. Thus the metal is forced to fill the die cavity by a powerful squeezing or pressing action, rather than by a succession of blows. Parts produced by hot pressing have also been called die-pressed castings, but the term casting in this connection is somewhat misleading.

Advantages of Brass Forgings: Brass forgings average 50,000 pounds per square inch tensile strength, as compared with 20,000 to 30,000 pounds per square inch for brass castings. Forgings are made of virgin metal. It is impossible to make a porous forging; while with castings it is difficult to know whether they will leak or not. Forgings are never scrapped or tested for leaks. Forgings contain no sand to dull and wear out tools, and consequently, the life of tools used on forgings is many times longer than that of tools used on sand castings. Forgings are clean, and alike as to strength, shape or size. When chucked, they run true and for this reason, less allowance for finish is required on a forging. Considerable saving can be shown on screw machine parts, where 30 per cent or more of the stock is turned into chips. If a part has a flange on it, or a hub on each side, it will be economical to forge it. Take the case of piano caster rollers made of bar stock; the bar stock costs $150 for a thousand parts: if forged, the material costs approximately $70 per thousand parts.

Composition of Forging Rod: The composition of forging rod for brass forgings varies little from a 60-40 mixture. The S.A.E. No. 88 specification of forging rod gives copper 58½ to 61½ per cent; lead 1½ to 2½ per cent; and the remainder, zinc. This material forges and machines freely.

Forging Equipment: Board drop-hammers for brass forging generally range from 400 to 2000 pounds, and the steam hammers from 300 to 1500 pounds. Gas, oil, or electric furnaces are used to heat the forging rod and slugs. Owing to the small permissible variation in the heat to get the best results, accurate temperature controls should be provided.

Brass Forging Dies: Dies for board-drop and steam hammers are made of a low-carbon steel. Their average life ranges from 50,000 to 150,000 forgings. This long life is made possible by spreading the operation over several sections of the die. Most dies have, in addition to the finished pair of die cavities, a roller to draw out the stock to a smaller section; a former to form it to the approximate shape of the die cavity; a blocker to prepare the bar to the approximate shape of the finished impression; and a cut-off to cut the forging off the end of bar.

Brass forging dies require approximately the same draft as

dies for steel. It is possible, when the sections are not too high, to use a draft of 3 degrees instead of 5 and 7 degrees as is customary on the deeper sections. Due to the softness of brass and copper, it is of the utmost importance to smooth and polish the dies very highly. If a scratch is left, the brass is driven into this crevice, and in a short time a crack will develop.

Accuracy of Brass Forgings: Forgings will vary by plus or minus 0.005 inch, on an average. If a part is 6 inches long, it will vary in length about 0.010 inch. In commercial practice, forgings may vary by plus or minus 0.0075 inch, unless otherwise specified. See Hot-pressed Brass Parts.

Brass, High. See High Brass.

Brass History in United States. Brass was produced in the American Colonies for the first time at the iron foundry of John Winthrop, Jr., in Lynn, Mass., in 1644. A brass industry, however, did not develop until over a century later. About 1750, John Allen established a brass factory in Waterbury, Conn., the brass being used chiefly in the manufacture of buttons. From this humble start the brass industry of the United States has grown to be a great industry.

Brass, Hot-Pressed. See Hot-pressed Brass Parts.

Brass Lathe. The "brass lathe" is so called because it is designed especially for operating on brass parts of various kinds. A typical machine is equipped with a screw-chasing attachment similar to the type found on Fox or monitor lathes, and the tailstock is mounted on a cross-slide. There is no tool carriage, but a T-rest for supporting hand-manipulated tools. When a turret is added to a lathe of this general design, it may be known either as a *turret lathe, Fox lathe,* or *monitor lathe.* The *square-arbor lathe* is also used for brass work and derives its name from the fact that the spindle or arbor of the tailstock is square instead of being cylindrical. The spindle is made square in order that it will better withstand torsional strains incident to tapping or drilling. This type of lathe has been widely used by brass workers, and has been regarded as a very effective type where work is done that does not require a multiplicity of tools and a monitor or turret lathe.

Brass, Low. See Low Brass.

Brass Pipe. Seamless brass pipe suitable for use in plumbing, boiler feed lines, etc., has the following compositions, in per cent, according to A.S.T.M. Specification B43-33:

Muntz Metal: Copper, 59 to 63; lead, 0.50 max.; iron, 0.07 max.; tin, 0.15 max.; zinc, remainder.

High Brass: Copper, 65 to 68; lead, 0.80 max.; iron, 0.07 max.; tin, 0.15 max.; zinc, remainder.

Admiralty Metal: Copper, 70 to 73; lead, 0.07 max.; iron, 0.07 max.; tin, 0.90 to 1.20; zinc, remainder. Note: The ideal composition for Admiralty Metal is 70 per cent copper, 29 per cent zinc, and 1 per cent tin. Better tubes will be obtained by adhering closely to this composition, particularly as to tin.

Red Brass: Copper, 84 to 87; lead, 0.07 max.; iron, 0.07 max.; tin, 0.15 max.; zinc, remainder.

Diameters: The actual outside diameters of brass pipes are the same as the outside diameters of steel pipes. For example, a 1-inch nominal size has an outside diameter of 1.315 in both steel and brass. See Pipe Corrosion.

Brass Rod. S.A.E. Standard Specification No. 88 applies to rods capable of being forged readily while hot and easily machined. These rods may be produced by hot-rolling or extrusion, and may be finished by cold-drawing, if necessary, to meet requirements as to size.

Composition: Copper, 58.50 to 61.50; lead, 1.50 to 2.50; iron, max., 0.15; materials other than copper, lead and zinc, max., 0.35 per cent; zinc, remainder.

Physical Properties: Hot-pressed forgings should have an ultimate strength of 45,000 and a yield point of 18,000 pounds per square inch. The elongation in 2 inches is 25 per cent.

Brass Rod, Free-Cutting. See Free-cutting Stock.

Brass Rod, Hard and Soft. The terms "hard" and "soft" as applied to brass rod have different meanings to the manufacturer and to the user. To the user, the term "hard," applied to brass rod, means that it is difficult to cut; the term "soft" means that it is easy to cut. To the manufacturer, the term "hard" means high tensile strength, stiffness, and high Brinell, scleroscope, and Rockwell hardness numbers, and does not necessarily mean that the rod is difficult to cut. The manufacturer uses the words "free-cutting" and "not free-cutting" to describe the cutting qualities.

In steel and iron, metal that has high strength and Brinell hardness is generally not free-cutting, and metal that has low strength and Brinell hardness is free-cutting. In brass, the same relation does not necessarily hold. In brass, the most important factor in determining free-cutting properties is the lead content. This should be maintained at about 3 per cent; if it runs much above this, trouble will be experienced in manufacture, and in the rod itself, due to lack of strength; if it runs below 3 per cent, the maximum free-cutting properties will not be attained. The difference in lead content explains why brass rod made abroad

does not cut so readily as similar stock made in this country. It also explains why tubing as a rule is "harder" (in the meaning of the user) than brass rod. If the lead content of brass tubing is higher than about 1 per cent, difficulty is met with in manufacture. The hardness (strength, stiffness, etc.) of brass is controlled largely by the amount that it is drawn, either from the extruded size or after the last annealing. This has comparatively little to do with the free-cutting properties of the rod. The rod should be drawn stiff enough so that the cutting tools will not push it out of shape. The required results are obtained by accurate control of the composition and processing of the rod.

Brass Sheets. There are three grades designated as A, B and C. Grades A and B are used for deep drawing. As the brass is used for many purposes requiring properties not indicated by ordinary physical test data, it is often advisable to obtain from the manufacturer brass having an anneal or temper adapted to actual requirements.

Temper of Sheet Brass: The tempers are designated as Quarter Hard (1); Half Hard (2); Three-Quarter Hard (3); Hard (4); Extra Hard (6); Spring (8); Extra Spring (10). The numbers following each temper designation represent the amount of reduction in B. & S. gage numbers when the brass sheets are rolled. The greater the reduction, the harder the brass.

Composition of No. 70: Copper, (Grade A) 68.50 to 71.50, (Grade B) 66 to 69, (Grade C) 64.50 to 67.50; lead, max., (Grade A) 0.07, (Grade B) 0.07, (Grade C) 0.35; iron, max., (Grade A) 0.04, (Grade B) 0.04, (Grade C) 0.06 per cent; zinc, max., (Grades A, B and C) remainder.

Brass Tubing. Seamless brass boiler tubes for locomotive boilers, according to A.S.T.M. Specification B14-18, has the following composition, in per cent: Copper, not under 69; lead, not over 0.50; iron, not over 0.10; materials other than copper and zinc, not over 0.50; zinc, remainder. These tubes are cold drawn to size.

Brass Wire. Brass wire is generally composed of from 64 to 74 per cent of copper and the remainder is chiefly zinc. The tensile strength ranges from 40,000 to 100,000 pounds per square inch, increasing with the percentage of zinc in the alloy.

Brass Wire for Springs: S.A.E. Standard No. 80 is used for making springs. Grade A is intended for severe service, and Grade B for ordinary conditions. Composition: Copper, (Grade A) 70 to 74, (Grade B) 64 to 68; lead, max., (Grades A and B) 0.10; iron, max., (Grade A) 0.06, (Grade B) 0.07 per cent; zinc, (Grades A and B) remainder.

This wire has a tensile strength of at least 100,000 pounds per

square inch, and it should be capable of being bent through an angle of 180 degrees around a wire of the same diameter without breaking.

Wire for Brazing: S.A.E. Standard No. 82 is suitable for brazing and torch welding. This wire should be soft annealed and the surface should be clean and free from scale or other foreign matter.

Composition: Copper, 59 to 62; lead, max., 0.30; iron, max., 0.06 per cent; zinc, remainder.

Brastil. A copper-base brass die-casting alloy having the color of white gold, with high strength and hardness and high resistance to corrosion, fatigue, and shock. Copper content, 81 per cent; tensile strength in die-castings, from 90,000 to 95,000 pounds per square inch; elongation, from 10 to 17 per cent in 2 inches; Brinell hardness, 160 to 180. Parts ordinarily made from steel because of the strength required can be cast from this alloy. Suitable for high-strength die-castings in general.

Brazed-Seam Process. A method for making brass tubing, in which a brass plate is bent into tubular form and welded or brazed at the joint. The brazed tube is afterwards drawn to size through dies.

Brazilian Corundum. A natural abrasive obtained from Brazil, containing about 76 per cent of crystalline alumina, which constitutes the cutting material of the abrasive. Brazilian corundum is not considered of as high a grade as *Canadian corundum.*

Brazing. Brazing is a method of joining metal parts together by means of an alloy known as *spelter solder,* or simply as *spelter,* which is melted into the joint and unites with the metals. Brazing is practically the same as *hard soldering,* but, according to the commonly accepted meaning of the two terms, there is the following distinction: Brazing means the joining of metals by a film of brass (a copper-zinc alloy) ; hard soldering is the term ordinarily applied when silver solder is used, the latter being an alloy of silver, copper, and zinc. For brazing, a red heat is necessary, and a flux (borax or boracic acid) is used to protect the metal from oxidation, and to dissolve the oxides formed. The part to be brazed is heated either by means of a blow-torch, gas forge, or a coke or charcoal fire. For very small work, an alcohol lamp or gas jet is often used, the heat being intensified by using a blowpipe. As a considerable amount of heat is required to melt the spelter solder, brazed work will withstand more heat without breaking or weakening than parts which are united by soldering. The chief advantage of a brazed joint, however, lies in its superior strength.

The ordinary process of brazing consists, briefly, in assembling the parts to be brazed, applying a suitable flux and the spelter solder (or hard solder) to the joint, and heating the joint until the spelter solder melts and unites with the parts to be joined. The method of holding the parts in place while brazing depends upon their shape. If practicable, they should be secured in such a way that the work can be turned over during the process of brazing without disturbing the relation of the parts, thus affording a better chance to apply the flux and spelter. Brazing is an operation requiring considerable experience. The secret of successful brazing is the thorough cleaning of the joint that is to be brazed. "Well cleaned is half brazed" is a true saying.

The principal difference between *dip brazing* and ordinary brazing is that the work is immersed into the spelter solder while the latter is in a liquid state. The spelter is contained either in a cast-iron tank or graphic crucible, the size of which depends upon the size of the parts to be brazed. *Muffle brazing* differs from ordinary brazing in that the parts to be united are enclosed in a tube or muffle. This insures uniform heating, clean smooth surfaces, and is especially adapted to brazing alloys, the melting temperatures of which are rather close to that of the spelter.

Brazing, Hydrogen Process. By the use of atmospheres of protective gas in electric furnaces, steel parts used in the manufacture of complicated assemblies can be united by a strong alloy weld. This method, known as hydrogen brazing, involves the welding together of the parts to be joined by means of a copper flux. The theory of the process involves the reducing action of a hydrogenated atmosphere, which thoroughly cleans the surfaces to be joined, and the capillary attraction of the fluid copper, causes it to diffuse quite generally over the surface and to be drawn into the minutest joints between the parts. The protective atmosphere is also essential during the cooling period, and for this reason the usual type of furnace cannot be used.

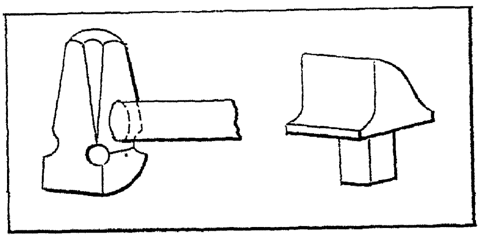
Bright Annealing Application: Another application on which the protective gas envelope is used to advantage is bright annealing steel in sheet or fabricated form, for nickel, monel and certain other non-ferrous metals, to save the cost of annealing pots, handling, pickling, etc. Heating takes place in only one portion of the furnace, the remainder being provided with a water jacket for cooling; thus the work is both heated and cooled in the protective gas atmosphere.

Brazing, Spelter Solder. The spelters employed in brazing are composed of alloys of copper and zinc. The melting point of copper-zinc alloys may be regulated by varying the percentage of zinc, the melting temperature decreasing as the proportion of

zinc increases. The fusing point of spelters should be as close as possible to that of the article to be brazed, as a more tenacious joint is thereby secured. An easily fusible spelter may be made from two parts of zinc to one part of copper, but the joint will be weaker than when a spelter more difficult to fuse is employed. A readily fusible spelter may be made with 44 per cent of copper. 50 per cent of zinc, 4 per cent of tin, and 2 per cent of lead. Alloys containing much lead, however, should be avoided, since lead does not transfuse with brass and thus decreases the strength of the joint. A hard spelter for the richer alloys of copper and zinc may be produced from 53 parts of copper and 47 parts of zinc. Brass spelter is sometimes used for copper and iron articles, as these metals have a much higher melting point than brass, thus allowing the use of a richer copper alloy. In these cases tin is often added as one of the ingredients, but it should be sparingly used as it increases the brittleness of the spelter. Ordinarily the spelter solder used for brazing is obtained from manufacturers of such supplies. In making brazing spelters, it is important that the metals used should be commercially pure, as impurities interfere with the color, malleability, and strength.

Break Clearance. The term "break clearance" is sometimes used to indicate the clearance between a blanking punch and its die. The purpose of this clearance is to reduce both the pressure required for the blanking operation and the strain on the punch; thus, the stock subjected to shearing action between the edges of the punch and die, breaks easier, which accounts for the name "break clearance."

Breaking-Down Tools. Breaking-down tools are used in blacksmith shops for "breaking-down" square shoulders upon work, part of which is to be drawn down to smaller dimensions. They are straight on one side of the face, the other being made circular (see illustration). Breaking-down tools should be made with the edge rounded, which will prevent leaving a cold shut where the shank joins body of a forging.



Breaking-down Tools

Breeze. Pulverized coke fuel used mainly for covering the bottoms of soaking pits and crucible furnaces for protecting the brickwork.

Brickwork, Furnace. See Furnace Brickwork.

Bridge Reamers. Taper reamers used in bridge and structural iron work are generally known as *bridge* reamers or *taper*

bridge reamers; they are employed for reaming the rivet holes in structural work, and are made either with a Morse taper or straight squared shank. The fluted part is tapered for part of its length and the remaining part is straight. The taper is 1 inch per foot for the ½ inch size, and increases to 1½ inch per foot for the 1¼ inch size.

Briggs Pipe Thread. The Briggs pipe thread (now known as the American Standard) is used for threaded pipe joints and is the standard for this purpose in the United States. It derives its name from Robert Briggs.

Bright Dip for Polishing. Where there are a great many brass parts to be finished, especially in shops where repair parts are refinished, a bright dip is commonly used. A piece that is badly tarnished, and that would ordinarily require a polishing or buffing operation, can be put into good condition quickly by the use of a bright dip. The parts are first thoroughly washed in a potash cleaning solution, in the same way that they are before plating. If several small pieces are to be bright dipped, it is advisable to wire them together, while in handling large pieces, a brass hook answers the purpose. After cleaning, the piece is first dipped into cold water and then into the *acid* bath. The acid solution is made of equal parts of commercial nitric and sulphuric acids; and a cupful of common salt is added to the contents of a 20-gallon crock. The piece must not be left too long in the acid—less than a second is often long enough—and one dipping is usually sufficient; but the experienced workman may find it advisable to dip a piece more than once, depending upon the nature of the metal.

Upon being taken from the acid, the piece is again dipped in cold water, after which it is dipped in a *cyanide bath* for an interval of a second or two, the purpose being to remove all signs of tarnish from the surface of the metal. In making up the cyanide solution, 1½ pounds of cyanide crystals are dissolved in a 20-gallon crock of water. In some cases, it may be found advisable to dip the work in the cyanide solution two or three times; no harm will be done if the work is left in it for several minutes. After being removed from the cyanide bath, the work is again dipped into cold water and then into hot water, to heat the metal so that it will dry quickly. If the drying takes too long, the work is likely to have a streaky appearance. For small work, it may be advisable to use a hot sawdust bath, which is simply a box filled with sawdust and having steam coils for heating to the required temperature.

Brinell Hardness Test. The Brinell test for determining the hardness of metallic materials consists in applying a known load

to the surface of the material to be tested through a hardened steel ball of known diameter. The diameter (or depth) of the resulting permanent impression in the metal is measured. The Brinell hardness number is taken as the quotient of the applied load divided by the area of the surface of the impression, which is assumed to be spherical. Thus

$$\text{Brinell No.} = \frac{\text{load on indenting tool in kilograms}}{\text{surface area of indentation in square millimeters.}}$$

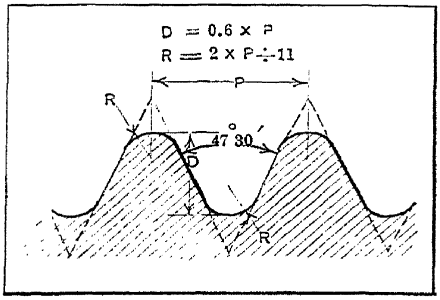
A standard ball 10 millimeters in diameter and a load of 3000 kilograms for hard metals and 500 kilograms for soft metals is standard practice. For extremely soft metals a load of 100 kilograms is sometimes used. The load should be applied for at least 10 seconds in the case of iron and steel, and at least 30 seconds in testing other metals. A period of 2 minutes has been recommended for magnesium and magnesium alloys. For testing very small specimens or very thin specimens, it is sometimes necessary to make Brinell hardness tests with a ball less than 10 millimeters in diameter.

Briquetting Metal Chips. The *Ronay process* for briquetting metal chips, without the use of a binding material, was developed by Arpad Ronay. This process subjects every part of the material to heavy hydraulic pressure, so great that a comparatively solid briquette is formed. In order to produce the greatest possible solidity, it is necessary that the air be thoroughly expelled. The air cannot be expelled if the pressure is exerted in the mold from one direction only. It is necessary to exert direct pressure on the briquettes from at least two sides. Briquettes produced by this process, in which all air is expelled, melt in the furnace with little or no more waste than pigs of new metal. The pressure employed approximates 35,000 pounds per square inch.

Britannia Metal. Britannia metal is an alloy containing tin, antimony, and copper as the chief ingredients. It is made in various compositions, many of which also contain zinc, lead, or bismuth. Britannia metal is used extensively in the manufacture of silver-plated ware. While the color of Britannia metal is white, it is almost invariably silver-plated. Britannia metal is made in much the same manner as babbitt metals, by first melting the copper in a crucible with a small percentage of tin or antimony. This mixture is afterwards added to the balance of the tin and antimony alloy. Several compositions of Britannia metal, determined by analysis, are as follows: Tin, 90 per cent; antimony, 6 per cent; copper, 2 per cent; bismuth, 2 per cent. Tin, 86 per cent; antimony, 10 per cent; copper, 1 per cent;

zinc, 3 per cent. Tin, 80 per cent; antimony, 10 per cent; copper, 3 per cent; zinc, 1 per cent; lead, 6 per cent. Tin, 70.5 per cent; antimony, 25.5 per cent; copper, 4 per cent.

British Association Thread. This form of thread is similar to the Whitworth thread in that the root and crest are rounded (see illustration). The angle, however, is only 47 degrees 30 min. and the radius of the root and crest are proportionately larger. This thread is used in Great Britain and, to some extent, in other European countries for very small screws. Its use in the United States is practically confined to the manufacture of tools for export. This thread system was originated in Switzerland as a standard for watch and clock screws, and it is sometimes referred to as the "Swiss small screw thread standard."



British Association Thread

British Standard Fine Screw Thread (B.S.F.). The form of this thread is the same as that of the Whitworth thread, but the number of threads per inch for a given diameter is greater than in the Whitworth standard system.

British Thermal Unit. The unit quantity of heat adopted in the English-speaking countries is the British thermal unit (B.T.U.). A British thermal unit is the quantity of heat that is required to raise the temperature of one pound of pure water one degree F. Strictly speaking, the measure or unit of heat is the quantity required to raise the temperature of one pound of water one degree, at its point of greatest density. Although this occurs at about 39 degrees F., it is customary, in ordinary computations, to disregard the temperature and to define a heat unit or British thermal unit simply as the quantity of heat required to raise the temperature of one pound of water one degree. The number of foot-pounds of mechanical energy equivalent to one British thermal unit is called the *mechanical equivalent of heat* and equals 778 foot-pounds. One foot-pound = 0.001285 heat unit. The various power equivalents of a British thermal unit are as follows: 1 B.T.U. = 1052 watt-seconds = 778 foot-pounds = 0.252 kilogram calorie (French or metric thermal unit) = 0.000292 kilowatt-hour = 0.000391 horsepower-hour = 0.00104 pound of water evaporated at 212 degrees F.

British Thermal Unit Values. See Heat Density; Heat Equivalent of Work; Fuel Oil Heating Value; Gasoline.

British Wire Gages. The standard British wire gage, usually known simply as Standard wire gage (frequently abbreviated S.W.G.), but also known as the New British Standard (abbreviated N.B.S.), and also frequently known as the British Legal Standard or Imperial wire gage, is the legal standard for wires in Great Britain, by order in Council, August 23, 1883. The Birmingham or Stub's iron wire gage is also used for some purposes, especially for designating the sizes of brass wire, but only to a limited extent. On the whole, it may be considered obsolete; while it is sometimes referred to as Stub's gage or Stub's iron wire gage, it should not be confused with the Stub's steel wire gage, which is still a commonly used gage for steel wire, drill rod, and drill diameters. The Birmingham wire gage is usually abbreviated B.W.G.

Broaching Process. Broaching consists in cutting away metal to obtain a given form, size and finish by using a broach (or several successive broaches in some cases) having a series of teeth which progressively increase in size or height from the starting end, so that each tooth takes a light cut and thus, by a succession of cuts, forms a surface quickly and accurately. In other words, the shape of the machined surface is a reproduction of the shape of the final cutting edges on the broach. Broaching is applied to many different classes of work. A simple example of internal broaching consists in forming a hole of square, hexagon, or other form from a drilled hole. Originally, broaching was restricted to internal work of this kind and to the cutting of keyways; but now many flat or other external surfaces are machined by this process.

Some machine parts are finished by broaching because it is the only practical method. In other cases, broaching is selected in preference to other methods because for certain classes of work, especially in interchangeable manufacture, it is more rapid, and, consequently, less expensive. Broaching, when properly applied, is also very accurate and leaves a finish of good quality. Generally speaking, broaches are expensive tools, but they often make it possible to machine either internal or external surfaces in a few seconds. This explains the extensive use of the broaching process in automotive and other plants where duplicate parts must be produced in large quantities and frequently to given dimensions within small tolerances.

Broaching Machines: The general function of a broaching machine is to supply the power required for broaching and provide whatever stroke and speed adjustments may be needed. The machine must also be equipped with a suitable work-holding fixture and with means of supplying a cutting fluid to the broach. Modern broaching machines, as a general rule, are operated

hydraulically rather than by mechanical means. Hydraulic operation is efficient, flexible in the matter of speed adjustments, low in maintenance cost and the "smooth" action required for fine, precision finishing may be obtained. The hydraulic pressures required, which frequently are 800 to 1000 pounds per square inch, are obtained from a motor-driven pump forming part of the machine and connected with the cylinder containing the broach-operating piston or plunger. Broaching machines for general use are so designed that the length of the stroke can be adjusted to suit the length of the broach. The broach length depends upon the number of teeth needed to remove a given amount of metal. The cutting speeds of broaching machines may be varied for different materials and operations. These speeds frequently are between 20 and 30 feet per minute, and the return speeds often are double the cutting speed or higher, to reduce the idle period.

Bromine. Bromine is one of the non-metallic chemical elements allied in its chemical relations to chlorine and iodine. Its chemical symbol is Br, and its atomic weight, 79.9. At ordinary temperatures it is a dark reddish liquid which is opaque except when in thin layers. It has a specific gravity of 3.2 at 32 degrees F. It changes from the solid to the liquid state at —7 degrees C. (+19 degrees F.); its boiling point is at 59 degrees C. (138 degrees F.); its latent heat of fusion equals 16.18 calories; latent heat of vaporization, 45.6 calories; and specific heat, 0.107. Bromine is slightly soluble in water. When dropped on the skin, it produces corrosive sores. The chief uses of bromine are in analytical chemistry, where it is of some importance on account of its oxidizing action. The salts of bromine are widely used in photography, especially bromide of silver. Bromine does not occur free in nature, but is manufactured mainly from magnesium-bromide.

Bronze. Bronze is an alloy composed mainly of copper and tin in variable proportions, and sometimes containing small percentages of zinc, antimony, lead, aluminum, phosphorus, or manganese. There are many compositions known as bronze.

S.A.E. Standard No. 62: This is a strong general utility bronze suitable for severe working conditions and heavy pressures. Typical applications include gears; bearings; bushings for severe service; valve guides; valve-tappet guides; camshaft bearings; fuel pump, timer and distributor parts; connecting-rod bushings; piston-pins; rocker lever; steering sector and hinge bushings; starting-motor parts.

Composition of No. 62: Copper, 86 to 89; tin, 9 to 11; lead, max., 0.20; iron, max., 0.06; zinc, 1 to 3 per cent.

Physical Properties: Tensile strength, 30,000 pounds per square inch; yield point, 15,000 pounds per square inch; elongation in 2 inches (or proportionate gage length), 14 per cent.

S.A.E. Standard No. 63: This general-utility bronze combines strength with fair machining qualities. It is especially good for bushings subjected to heavy loads and severe working conditions. It is also used for fittings subjected to moderately high water or oil pressures.

Composition of No. 63: Copper, 86 to 89; tin, 9 to 11; phosphorus, max., 0.25; zinc and other impurities, max., 0.50; lead, 1 to 2.50 per cent.

Physical Properties: Tensile strength, 30,000 pounds per square inch; yield point, 12,000 pounds per square inch; elongation in 2 inches (or proportionate gage length), 10 per cent.

S.A.E. Standard No. 660: This composition is widely used for bronze bearings. Typical applications in the automotive industry include such parts as spring bushings, torque tube bushings, steering-knuckle bushings, piston-pin bushings, thrust washers,

Composition of No. 660: Copper, 81 to 85; tin, 6.50 to 7.50; lead, 6 to 8; zinc, 2 to 4; iron, max., 0.20; antimony, max., 0.20; other impurities, max., 0.50 per cent.

Physical Properties: Tensile strength, 30,000 pounds per square inch; yield point, 14,000 pounds per square inch; elongation in 2 inches (or proportionate gage length), 18 per cent.

S.A.E. Standard No. 67: This is a soft bronze with good antifriction qualities. Water-pump bearings represent one application.

Composition of No. 67: Copper, 76.50 to 79.50; tin, 5 to 7; lead, 14.50 to 17.50; zinc, max., 4; iron, max., 0.40; antimony, max., 0.40; other impurities, max., 1 per cent.

Physical Properties: Tensile strength 20,000 pounds per square inch; elongation in 2 inches (or proportionate gage length), 10 per cent.

A number of other bronzes are made with varying compositions. *Bell metal* is a bronze containing 80 per cent of copper and 20 per cent of tin, and the metal used for Chinese gongs is a bronze of similar composition. The name "bronze" is also used for alloys with copper and various other metals, even when these alloys are nearly or entirely lacking in tin; thus, for example, aluminum bronze is mainly an alloy of copper and aluminum. See also Manganese-bronze; Non-gran Bronze; Phosphor-bronze; Silicon Bronze; Tobin Bronze; Aluminum Bronze.

Bronze, Early Use. Copper was first produced from ores about 5000 years before the Christian era. About this time bronze became known, not by melting copper and tin together, but rather because the ores available contained tin, nickel and small amounts of other metals, and produced alloys harder and stronger

than copper. The Bible mentions Tubal Cain as a worker in brass and refers to the alloy in several places. There is reason to believe that not brass but bronze is intended. In the first century Dioscorides makes the earliest unmistakable reference to brass (an alloy of copper and zinc); nevertheless, it was known to the Far East long before. Owing to confusion in names, no approximation of a definite time when brass came into use is possible.

Bronze Gear Castings. See Gear Castings, Bronze.

Bronzing. Bronzing is a process by means of which a bronze-colored surface is produced on objects made from other metals or from wood, plaster, or other materials. A bronze-like color can be produced by exposing iron or steel parts to the vapors of heated *aqua regia,* then dipping them in melted vaseline, and finally heating them until the vaseline begins to decompose, when they are wiped off with a soft cloth. Bronze-like colors may also be produced by slightly heating the work, covering the surface with a paste of antimony chloride, also known as "bronzing salt," and letting the object stand until the desired color is obtained. The paste of bronzing salt may be made more active by adding a small quantity of nitric acid. Bronze colors can also generally be produced on metals by the action of dilute nitric acid and sal-ammoniac. The so-called "antique bronze" appearance is produced by painting over the bright metal with a solution of sal-ammoniac, cream of tartar, silver nitrate, and common salt. Plaster and wood are bronzed by first coating the articles with a sizing and then covering them witih a bronze powder produced by powdering brass or bronze.

Brown & Sharpe Taper. A standard taper used for taper shanks on tools such as end mills and reamers, the taper being approximately ½ inch per foot for all sizes except for taper No. 10, where the taper is 0.5161 inch per foot. Brown & Sharpe taper sockets are used for many arbors, collets, and machine tool spindles, especially milling machines and grinding machines. In many cases there are a number of different lengths of sockets corresponding to the same number of taper; all these tapers, however, are of the same diameter at the small end.

Brown & Sharpe Wire Gage. The Brown & Sharpe wire gage, also known as the American wire gage, is the gage universally recognized in the United States as the standard gage for copper wires and wires of metals other than steel. The diameters of the wires of successive numbers increase according to a geometrical ratio. The diameter of each succeeding number can be found by multiplying the diameter of the preceding number by 1.123, this being the ratio of the geometrical progression. The basic size is No. 36 wire, which is 0.005 inch in diameter.

Brushes, Motor. The brushes of a direct-current machine are those parts of the mechanism which, being held in some form of flexible holder, rest upon the commutator surface at proper points about its periphery and distribute current to or from the commutator segments. The brushes also perform the function of uniting the commutator segments to which are connected adjacent coils to be commutated, thus making a proper continuous circuit around the armature. They are made of a conducting material, generally of graphite or carbon, although metal or metal compound brushes are used extensively in some special applications. The brush material, being relatively soft, forms a good surface of contact with the commutator, thus reducing the resistance to the passage of current between the commutator and the external source of power to a minimum. The brush rigging or holders and mountings must be such as to afford minimum inertia to the brush, since its function is to aid the brush in following the more or less uneven surface of the commutator when the latter revolves.

Brush-Shifting Motor. A brush-shifting motor is an electric motor consisting of a stator with a three-phase distributed winding or a single phase winding and a rotor similar to that of a regular direct-current motor, but with a larger number of brushes which can be shifted through worm-gearing by means of a handwheel. This type of motor is used in order to obtain speed control, as it may be started, accelerated, stopped, and reversed by shifting the brushes.

Bucket Conveyors. Bucket conveyors consist of a series of equally spaced buckets attached either to a belt or a chain. Grain conveyors are always encased in wooden and steel casings, and the casings are nearly always vertical. The usual support for the buckets in this case is belting—either leather, cotton, or rubber. For coal, coke, and other heavy materials, the buckets are fastened to chain links, either single or double strand, depending upon the capacity for which the conveyor is designed; and, in this case, the conveyor casing is usually carried in a slanting position. Conveyors in a vertical position are only suitable for specifically light material and can be run at a circumferential velocity of from 250 to 350 feet per minute. Conveyors for heavy material must be wholly or partially inclined to give a clean delivery without scattering, and they should run at a speed of from 50 to 160 feet per minute. Bucket conveyors should always be driven from the top so that the upward side of the conveyor (the side containing the load) can be tight, while the empty side will run slack.

Bucket Elevator. A device practically the same as a *bucket conveyor,* except that it is used in a vertical or nearly vertical

direction. It consists chiefly of a belt or detachable link chain to which buckets containing the material to be lifted are attached, the belt or chain passing over pulleys or sprockets at the top and bottom. The top pulley or sprocket is power-driven.

Bucking. An electrical term used to designate the condition where the potential from one source is opposing that from another source.

Buckwheat Coal. Small coal of such size that the pieces will not pass a screen of $\frac{3}{8}$-inch mesh, but pass a screen of $\frac{1}{2}$-inch mesh. Buckwheat coal is often used for power plant purposes.

Buffing. Buffing is the process of obtaining a very fine surface, having a "grainless" finish, on metal objects, by means of soft wheels of felt to which a fine polishing material is applied, or by wheels formed of layers of cotton cloth. The term "buffing" is often used interchangeably with "polishing." The operation is performed with any wheel to the face of which the abrasive is loosely applied, rather than glued as in polishing. Buffing is not so harsh an operation as polishing. The abrasives which are glued to a polishing wheel are intended to grind away roughness that the grinding wheel or other cutting tool leaves—unevennesses that are often discernible only with the aid of a microscope. Buffing, on the other hand, employs such soft cutting materials as tripoli, lime, crocus or rouge prepared in cake form with tallow and other greases as a body, this being applied to the cloth buff by hand from time to time so that the face of the buff is given a coating of this composition. Some metals, like German silver and white metal, are buffed before plating. Pocketknife blades are polished with emery and then highly finished (colored) by what is known as "crocus polishing," in which a wheel, similar to a leather-faced wood polishing wheel is used for buffing. Steel parts to be plated are usually prepared for plating by polishing, buffing being employed to give a luster to the plated surface. The term *sand buffing* relates to the finishing of German silver, white metal, and similar materials. As compared with the ordinary buffing operation that is used only to produce a very high finish, sand buffing actually removes considerable metal as in rough polishing or flexible grinding. For sand buffing, rotten-stone and pumice are loosely applied.

Buffing Machines. See Polishing or Buffing Machines.

Buffing Wheels. Buffing wheels are manufactured from disks (either whole or pieced) of bleached or unbleached cotton or woolen cloth, and used as the agent for carrying abrasive powders, such as tripoli, crocus, rouge, lime, etc., which are mixed with waxes or greases as a bond. There are two main classes

of buffs known as the "pieced-sewed" buffs, which are made from various weaves and weights of cloths, and the "full disk" buffs which are made from the best sheeting and shirting. Bleached cloth is harder and stiffer than unbleached cloth, and is used for the faster cutting buffs. Coarsely woven unbleached cloth is recommended for highly colored work on soft metals, while the finer woven unbleached cloths are better adapted for the harder metals. A stiff buff when working at the usual speed is not suitable for "cutting down" soft metal or for use on light plated ware, but is used on the harder metals and for heavy nickel-plated articles.

Buffing Wheel Sizes. Full disk buffing wheels recommended by the polishing industry for general adoption are all 20 ply and have the following outside diameters: 4, 5, 6, 7, 8, 11, 13, 14, 17, 18 and 20 inches. This "simplified practice" recommendation of the Bureau of Standards has been accepted by the Grinding Wheel Manufacturers' Association of United States and Canada, the Metal Finishing Equipment and Materials Institute, the Metal Polishers' International Union, and by various other associations, as well as by numerous manufacturers.

Buffington Process. A method for producing a protective oxide coating on iron and steel. The articles to be coated are immersed cold in a molten bath of manganese dioxide and potassium nitrate; the articles are next removed and hung over the iron pot in which the bath is contained, so as to be exposed to the fumes from the mixture. They are then placed in boiling water. Colors varying from blue to bronze may be produced in this manner.

Built-Up Section. A structural beam, column, or strut, composed of two or more single structural shapes.

Bulging Method of Forming Shells. In the manufacture of many sheet-metal parts, operations, such as bending, forming, and expanding can be performed economically by the hydraulic bulging method. The work is placed in a die, which is usually split, and water under a pressure varying from 600 to 1200 pounds per square inch is admitted from either a hydraulic accumulator or a force gump. A force pump is generally sufficient for the purpose, and gives a ready means of varying the fluid pressure; the initial cost is also low. In the case of hollow work, the water under pressure is admitted directly into the work itself, so that in this respect it differs from the older method of hydraulic bulging, in which the quantity of water is measured, put into the receptacle to be bulged, and the operation performed under a power press.

With the improved method, a power press is not required, and the construction of the dies is so simple that their first cost is much less than when the combined mechanical and hydraulic operation is employed. Furthermore, the method of operation does not depend for its success upon the watchfulness of the operator in measuring the fluid. It is merely necessary to insert the work in the lower half of the dies, clamp the top half in position, admit the water under pressure from a suitable water cock and drain the water off after the piece has been formed. Another advantage of the process is the rapidity with which the water pressure forms the article to the desired shape, the time required being not more than one-sixth that taken by the other method. An important point to be considered is the water pressure, which must be governed by the thickness of the metal and its physical characteristics. A safe pressure to use at first is about 700 pounds per square inch for annealed brass 0.020 inch thick, increasing this to approximately 1200 pounds per square inch for a thickness of 0.060 inch.

Bull Block. In wire drawing, a bull block is a machine in which wire or rod is drawn in order to reduce it into wire of the required diameter.

Bull Center Reamer. A conical reamer used for reaming the ends of large holes—usually cored—so that they will fit on a lathe center. The cutting part of the reamer is generally in the shape of a frustum of a cone. It is also known as a pipe center reamer.

Bulldozer. The bulldozer is a machine especially adapted for bending operations, and is closely allied to the forging machine; in fact, many operations can only be done successfully on forging machines when the bulldozer is used for performing a preliminary operation. This type of machine contains a cross-head which carries one member of the forming dies; the other member of the dies is held against a die seat which is formed integral with the main base of the machine. This base or bed is horizontal and the cross-head slides upon horizontal ways or ways which are slightly inclined. The stock to be formed is placed between the dies, and, as the cross-head moves forward, the stock, which may or may not be heated, is bent to conform to the shape of the dies, the work as a rule being completed in one movement of the cross-head. While the machine is quite simple in construction and operation, many interesting types of forming tools and dies are employed on different classes of bulldozer work. Many of the tools or dies are made of cast-iron, in order to reduce the cost, and those parts of the dies which are subjected to wear are faced with hardened steel plates which may

readily be replaced, if necessary. Whenever hot punching or cutting is done, high-speed self-hardening steel should be used for the working members of the tool.

Bull Wheel. The gear in a planer drive which meshes with the rack beneath the platen and through which the motion of the platen is obtained.

Bunsen Burner. The device known as the "Bunsen burner" was invented in 1855 by Prof. R. W. von Bunsen of Heidelberg, and provides a simple means for burning ordinary coal gas with an extremely hot smokeless flame. The object of the burner is to procure a flame capable of producing great heat, but which will not smoke any vessel or article heated by it. The force of gas, escaping through a small aperture, draws the air through holes in a sleeve surround the jet. The air and gas mix together, consuming the carbon produced by the decomposing gases before it becomes incandescent, and producing the flame desired.

Bunsen Cell. The Bunsen cell is one of the well-known primary electrical batteries which is, in general, similar in construction to the Daniell cell in that a zinc plate is placed in dilute sulphuric acid, but in the Bunsen battery the copper cylinder is replaced by one of carbon, and the copper sulphate solution, by strong nitric acid. The Bunsen cell gives a high electromotive force, varying from 1.9 to 1.95 volts. It has also low internal resistances, and can, therefore, be used for producing fairly large currents. The battery give off fumes of nitric peroxide and must, therefore, be placed in the open air or under an exhaust flue. The battery must be taken apart when not in use, because the mixing of the liquids through the walls of the porous jar containing the dilute sulphuric acid would render it useless after a short time. The porous jar should be placed in water after having been used, so that the zinc sulphate solution may be dissolved out of the pores of the jar. Otherwise, when the jar dries, the zinc sulphate solution will crystallize in the pores and cause the jar to crumble to pieces.

Buoyancy. Any body that is immersed in water, or in any other liquid, is subjected to an upward force equal to the weight of the mass of the liquid that is displaced by the body. This is true whether the body sinks or floats. The weight of a floating body is equal to the weight of the volume of the liquid that it displaces. The upward pressure on the body is known as *buoyancy.* It may be assumed to be exerted at the center of gravity of the displaced liquid, which point is known as the *center of buoyancy.* In a floating body, at rest on the water, the line joining the center of gravity of the body and the center

of buoyancy is always vertical, and is known as the *axis of equilibrium.* If an external force causes this axis of equilibrium to occupy an inclined position, then, if a vertical line be drawn upward from the new center of buoyancy to this axis, the point where it intersects the axis is called the *metacenter.* If the metacenter is above the center of gravity, the body is in stable equilibrium, and tends to return to the original position when the external force is removed.

Weight of Submerged Body: A body submerged in water or other fluid will lose in weight an amount equal to the weight of the fluid displaced by the body. This is known as the *principle of Archimedes.* To illustrate, suppose the upper surface of a 10-inch cube is 20 inches below the surface of the water. The total downward pressure on the upper side of this cube will equal the area of the side multiplied by the product of the depth, in inches, to which the surface is submerged and the weight of 1 cubic inch of water. Thus, the downward pressure equals $10 \times 10 \times 20 \times 0.03617$ (weight of 1 cubic inch of water) $= 72.34$ pounds. The upward pressure on the under side equals $10 \times 10 \times 30 \times 0.03617 = 108.51$ pounds. The weight of the water displaced by the body equals $10 \times 10 \times 10 \times 0.03617 = 36.17$ pounds; and $108.51 - 72.34 = 36.17$ pounds. This excess of upward pressure explains why it is comparatively easy to lift a submerged stone or other body.

Bureau of Standards. One of the important functions of the U. S. Bureau of Standards is to compare with its own standard of measurements, the measuring instruments used by states, cities, scientific laboratories, educational institutions, and commercial corporations. The Bureau also gives advice concerning these standards and their use, and many questions of disagreement either between corporations, or between the public and a corporation, involving the use of standards, are referred to the Bureau for advice or adjustment. The Bureau also certifies the accuracy of standards of measurement, such as gages, and in addition publishes a great deal of information relating to measurements and standards of all kinds, in the form of small booklets, each dealing with one definite subject. Numerous tests and investigations are carried on in this connection. The materials of construction are also dealt with by the Bureau. The activities of the Bureau of Standards are fundamentally concerned, either directly or indirectly, with the improvement of methods of production or the quality of the output of the industries.

"Burning On" or "Casting On." The expressions "burning on" or "casting on" relate to a method of repairing or of

filling in a broken part of the casting. Thus if a part has been broken from a casting it may be reunited or a new part formed, by pouring molten metal over the surface that is to be repaired until it becomes plastic or begins to melt. Two pieces that have broken apart can be united by chipping away the edges to expose the surfaces that are to be burned. They are then placed together and a core fitted around them leaving the entire top side exposed. An overflow channel is made in the core to carry the surplus metal away. The burning is accomplished by pouring a constant stream of metal onto the break until the surfaces become plastic, when the pouring is stopped, leaving the opening between the break filled with metal. There is usually quite a lot of metal to chip away after burning, but many castings have been saved by this operation, especially prior to the introduction of modern welding processes.

Burnishing. The burnishing of metals is a method of securing smooth finished surfaces by compressing the outer layer of the metal, either by the application of highly polished tools, or by the use of steel balls which, by rolling contact, produce smooth surfaces.

Burnishing of Spun or Drawn Shapes: After sheet metal is spun, or drawn in presses, the smooth, even surface which it has when it comes from the mills is changed to a rough, uneven surface having high and low spots which are hardly noticeable to the naked eye, but very easily distinguished under the magnifying glass. The working operations distend or elongate the molecules, and the annealing operation restores them to their original shape. Some shells are annealed several times before the burnishing operation is reached, besides being pickled after each annealing to remove the scale; this leaves the surface of the metal in a matted condition, as well as soft and without temper.

A spun shell can be gone over with a planisher, and hardened, but the scale and dirt is crowded into the grain of the metal and the only way to obtain a smooth surface is to buff or cut it down until this pitted face is removed, thus wasting about 10 per cent of the metal. The spinner can do this in another way, that is by skimming or shaving the uneven surface, but even more metal is wasted than by buffing, and the shell is also weakened by gouging the high places. This same shell could be left without polish, and the chuck transferred to the burnishing lathe, which runs at much greater speed than one used for spinning. After the shell is dipped right to remove all spinning dirt and scale, it can then be polished to an even surface, the uneven face of the metal being amalgamated or smoothed down to a bright surface of the proper temper; it is then colored

with a cloth buff to obtain a perfect finish. The gage or thickness remains the same, as there is no dirt or scale to buff out. It is necessary to have a metal chuck in burnishing, and where the shell has been spun on such a chuck, the latter can be used for both operations. Some work can be lacquered without coloring on the buff wheel, the only operation after burnishing being to wash in hot water and dry at once in hot sawdust.

Burnishing Tools: Burnishing tools are made extremely hard and no temper is drawn. These tools have to be re-polished when they become coated with metal, the interval between polishings depending upon the texture of the metal worked and its temper, a shell that has been annealed several times coating the tool more than one that has not. The end of a burnisher may be polished quickly. A board of soft wood is used, or a strip of leather fastened to a board and to the bench, in a position convenient to the operator. Grooves are worn into the leather or board, and flour of emery and oil, or flint flour and water, is used to clean the tools, a few passes of a tool being all that is necessary to polish it.

Cleaning Work for Burnishing: The bright dip which is used to clean work before burnishing is composed of oil of vitriol (sulphuric acid), 2 parts; aqua fortis (nitric acid), 1 part. This solution should be kept in a crock set in a tank of running water, and mixed 7 or 8 hours before using, as the acids when combined heat up. It is best to mix the acids the day before using. In dipping brass, copper, and German silver, the parts are strung on a stiff brass or copper wire whenever possible. If there are no holes in the metal that can be used for stringing, they can be put in a metal or crock basket, but they cannot be handled to good advantage as it is very difficult to thoroughly wash and dip them. The work should be washed in boiling potash, and then dipped in cold water to clean the potash off and cool the metal. After cooling in the water, the parts are dipped for a few seconds in the acids, and are kept constantly in motion, so that the surfaces will be all exposed equally; they are then shaken thoroughly above the acid and immediately washed in two separate cold-water baths, then in hot soapy water, and finally in hot water, after which they are dried at once in hot sawdust. This operation will leave a bright, clean surface free from acid.

Lubricants for Burnishing: Common yellow soap, dissolved to thick paste, may be used as a lubricant when burnishing brass. The shells and the finger pads are dipped in clear water, and the tool is dipped in the soap paste before burnishing each shell. A lubricant for copper is made by dissolving about one ounce of ivory or castile soap in a gallon of water. The shells and

pads are dipped in this solution, no lubricant being used on the tool. Yellow soap should not be used on copper, as the action of the resin on copper is different from that on brass, the metal being so glazed or greased that the tool works badly. For copper plate on steel, such as copperized steel oilers, etc., about one-half ounce of oil of vitriol to four gallons of water should be used. The burnishing tool should be dipped in a mixture of mutton tallow that has been melted with 5 per cent of beeswax, and the work and the finger pads should be dipped in the acid mixture. The tool is lubricated in the tallow mixture before burnishing each shell.

For German silver, the shell should be dipped in clear water, the finger pads in sour beer, and the tool in yellow soap paste. For white metal or britannia, use ivory or castile soap in the paste form for the tool, and sour beer or ox gall in water (4 ounces to the gallon) for the finger pads. Wash the work in hot alkali water (a spoonful of cream of tartar, saleratus or soda to a pail of water), and dry in hot sawdust. For burnishing work which is to be lacquered, without coloring on the cloth buff, use thin glue for a lubricant, and also on the finger pads. When the part is burnished, put it in saleratus water to keep it from tarnishing; then wash in hot water and dry in hot sawdust.

Burnishing Broach. This is a broach having teeth or projections which are rounded on the top instead of being provided with a cutting edge, as in the ordinary type of broach. The teeth are highly polished, the tool being used for broaching bearings and for operations on other classes of work where the metal is relatively soft. The tool compresses the metal, thus making the surface hard and smooth. The amount of metal that can be displaced by a smooth-toothed burnishing broach is about the same as that removed by reaming. Such broaches are primarily intended for use on babbitt, white metal, and brass, but may also be satisfactorily used for producing a glazed surface on cast iron. This type of broach is also used when it is only required to accurately size a hole.

Burnishing by Ball Process. Barrel burnishing is done to finish, polish, or brighten metal parts without cutting away the stock, steel balls acting as individual burnishing tools. Tilting barrels are sometimes used for ball burnishing when the work is small, but the horizontal type is universally recommended. The hardened and polished steel balls roll over the work while under pressure, and rub against the parts evenly. The pressure is caused by the weight of the balls and the work in the barrel. Some manufacturers claim that a horizontal barrel, large in

diameter and comparatively small in width, is the best type to use, because a certain quantity of balls will not spread over so large a space, and will therefore create a greater pressure on the work. In this type of barrel, about two pecks of steel balls should be used for one peck of work, and to this should be added a sufficient quantity of soapy water to rise one inch above the contents of the barrel. Soapy water serves as a lubricant. About six ounces of pure soap or soap chips without much alkali should be put in each pail of water. Another manufacturer claims that a barrel of small diameter, and comparatively long, completely filled with work, balls, and soapy water, is more efficient than the type just mentioned. It is said that the work then passes constantly and evenly through the mass of balls without bumping and falling against each other.

Polygon-shaped barrels prevent the work from bunching together and sliding instead of tumbling inside the barrel. Balls from 1/16 to ¼ inch in diameter are generally used, the size depending on the work and dimension of the cavity or corners in the pieces; the balls should be small enough to enter all cavities, and to insure this, a round steel slug with a fin-like edge is sometimes used. Articles to be barrel-burnished must be cleaned and must be free from oil or dirt. Double and triple burnishing barrels permit of burnishing more than one class of work at a time. Burnishing barrels permit the finishing of hundreds and thousands of small pieces at one time quickly and inexpensively.

Burnishing Dies. When an exceptionally good finish or polish is required, blanks which have been trimmed in a shaving die are pushed through what is known as a *burnishing* die. Such a die has an opening which tapers slightly inward toward the bottom, and it is finished very smooth, so that, when the blank is forced through by the punch, the metal around the edges is compressed and polished. Naturally, the degree of finish on the blanks will depend largely upon the finish of the burnishing surface of the die.

Burnishing Lathes. A burnishing lathe is smaller than a spinning lathe, and it has only one speed although the speeds of different lathes are varied to suit the work. The countershaft is fastened to the floor under the lathe; this is necessary on account of the great speed; besides a downward pull of the driving belt causes less vibration than the upward pull of a belt from an overhead countershaft. The burnishing is done by pushing the tool over the work, beginning at the front end and pushing always against the chuck or form over which the work is held. The toolpost is used as a fulcrum and the tool, which is pressed

against the work, as a lever. The tool is given a slight rotary motion, and only the thin edge or end is used. While the pressure against the work is not great, the area in contact with the metal is so small, and the speed of the lathe so high, being from 3200 to 5000 revolutions per minute, that the tool leaves a bright surface. The skill of the operator lies in passing the tool over the metal so as to leave a continuous bright surface without any trace of the tool marks; to do this the tool must be fed with regularity and without overlapping or leaving any dull places.

Burnishing Roller. The roller type of burnishing tool is sometimes used in machine shops, especially railway repair shops, for rolling the cylindrical surface of a journal, crankpin bearing surface, etc., in order to obtain a smooth dense finish. The burnishing tool consists of a hardened roller or disk which is supported by a shank held in the lathe toolpost. The leading edge or side of this disk is rounded and the burnishing is done by feeding the roller over the surface the same as in turning. The roller may be mounted on a plain bearing, but tools of improved design are equipped with roller bearings.

Burring Machines. Special machines and tools are sometimes used to remove the burr left on machine parts by cutting tools. One design of machine is intended especially for slightly countersinking the rear ends of holes in parts produced in automatic screw machines to remove the burr left by the cutting-off tool. This machine is semi-automatic. The parts are fed by hand into a chute and are pressed against a gage-block by a reciprocating link attached to toggle levers which exert sufficient pressure to prevent the part from rotating during the burring operation. When the link withdraws to transfer another part from the bottom of the chute, the burred blank drops out of the fixture. The burring is performed by a tool held in the spindle of an automatic sensitive drill head.

Gear Burring Machine: A machine of this type is designed for removing the burrs left on the ends of gear teeth after the hobbing or cutting operation. One type of machine is provided with a burnishing tool and a shearing tool. The burnisher resembles a hob without gashes, and it meshes with the gear, thus forcing the burrs to project from the ends of the teeth at an angle so that the stationary shearing tool can readily cut them off.

Bus-Bars. The common connections to which several generators deliver their current, and from which several feeders draw their supply, are termed *bus-bars* or *busses.* These busses may be solid copper wire, tubing, or flat bars, depending upon the amount of current to be carried. Flat bars are usually 2, 3, 5,

or 10 inches wide, and 1/8 or 1/4 inch thick. These are, whenever possible, mounted on edge, with spaces between the laminations equal to the thickness of the bars, to allow free circulation of air to assist in cooling the bars. For small capacities, round solid wire is used, and for high voltages and long spaces, tubing is often used. Investigations have shown that the cross-section necessary to carry a given current varies with the nature of the current; for instance, bus-bars heat more when carrying 60-cycle alternating current than with lower frequency or direct current.

Bushel. See Dry Measure.

Bushing. A lining or sleeve that is inserted in a hole usually to provide convenient means of restoring a worn hole to its original size by inserting a new bushing. A "bushing" is also a pipe fitting which is used for the purpose of connecting a pipe with a fitting of larger size; it is a hollow plug with internal and external threads to suit the different diameters.

Bushing Bronze. See under Gear Castings, Bronze.

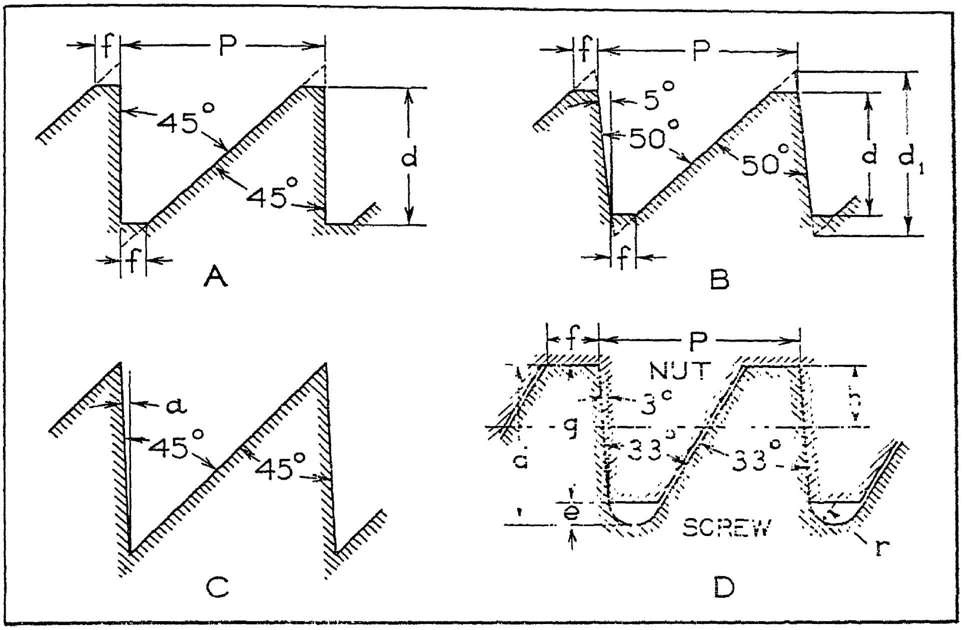
Bushing Chain. What is known as the built-up block or bushing chain resembles somewhat a roller chain, but differs from the latter in that the bushings between the side links are not provided with rollers. The operation of this rollerless chain is similar to that of the solid block chain. It will fit sprockets intended for roller chains, provided the pitch and diameter of the rollers are of corresponding size. These chains are recommended when considerable power is to be transmitted and the speed is low. The rivet wearing surface is large in proportion to the pitch of the chain.

Bushings, Grinding Wheel. See Grinding Wheel Bushings.

Busses. A term sometimes applied to bus-bars. See Bus-Bars.

Butt Joint. A joint made either by welding or riveting, in which the two ends of the plates joined are abutted squarely against each other without overlapping. In the case of the riveted butt joint, the two ends of the plate are usually riveted to two plate strips that straddle the joint above and below.

Button Locating Method. This is a method employed for accurately locating work such as jigs, etc., especially on the faceplate of a lathe. This method is so named because cylindrical bushings or buttons are attached to the work in positions corresponding to the holes to be bored, after which they are used in locating the work. These buttons, which are ordinarily about 1/2 or 5/8 inch in diameter, are ground and lapped to the same size, and the ends are finished perfectly square. After the buttons are all set in correct relation with each other and have been



Screw Threads of the Buttress Type

tightened, the work is mounted on the faceplate of the lathe, and one of the buttons is set true with the axis of the lathe by the use of a test indicator. This button is next removed; the hole is then drilled nearly to the required size, after which it is bored to the finish diameter. In a similar manner, the other buttons are set in the central position, one after another, and the holes bored. It is evident that if each button is correctly located and set perfectly true in the lathe, the various holes will be located at the required center-to-center dimensions within very close limits. When a precision jig-boring machine is available, the button method is not required.

Buttress Threads. Screw threads of the buttress type are designed to resist heavy axial loads in one direction. Diagram *A* shows a common form. The front or load-resisting face is perpendicular to the axis of the screw and the thread angle is 45 degrees. The pitch of the thread may be the same as for the American standard or the Whitworth standard. According to one rule, the pitch $P = 2 \times$ screw diameter $\div$ 15. The thread depth d may equal $\frac{3}{4} \times$ pitch, making the flat $f = \frac{1}{8} \times$ pitch. Sometimes depth d is reduced to $2/3 \times$ pitch, making flat $f = 1/6 \times$ pitch.

Load-resisting Side Inclined: The load-resisting side or flank may be inclined an amount (diagram *B*) ranging usually from 1

to 5 degrees to avoid cutter interference in milling the thread. With an angle of 5 degrees and an included thread angle of 50 degrees, if the width of the flat f at both crest and root equals $\frac{1}{8} \times$ pitch, then the thread depth equals 0.69 $\times$ pitch or $\frac{3}{4}\ d_1$. Diagram C shows a buttress thread of the sharp vee form with a front face angle a of 1 degree; some flat or rounding, however, at the crest and root of any screw thread is preferable.

Saw-Tooth Thread: The saw-tooth form of thread illustrated by diagram D is known in Germany as the "Sägengewinde" and in Italy as the "Fillettatura a dente di Sega." Pitches are standardized from 2 millimeters up to 48 millimeters in the German and Italian specifications. The front face inclines 3 degrees from the perpendicular and the included angle is 33 degrees.

The thread depth d for the screw $=$ 0.86777 $\times$ pitch P. The thread depth g for the nut $=$ 0.75 $\times$ pitch. Dimension $h =$ 0.341 $\times$ P. The width f of flat at the crest of the thread on the screw $=$ 0.26384 $\times$ pitch. Radius r at the root $=$ 0.12427 $\times$ pitch. The clearance space e between the root of the screw thread and the crest of the nut $=$ 0.11777 $\times$ pitch.

Butt-Welded Pipe. Skelp used in making butt-welded pipe comes from the rolling department of the steel mills with a specified length, width, and gage, according to the size of pipe for which it is ordered. The edges are slightly beveled with the face of the skelp, so that the surface of the plate which is to become the inside of the pipe is not quite as wide as that which forms the outside; thus when the edges are brought together they meet squarely. The skelp for all butt-welded pipe is heated uniformly to the welding temperature. The strips of steel, when properly heated, are seized by their ends with tongs and drawn from the furnaces through bell-shaped dies or "bells," as they are called. The inside of these bells is so curved that the plate is gradually formed in the shape of a tube, the edges being forced squarely together and welded. For some sizes, the pipe is drawn through two bells consecutively at one heat, one bell being just behind the other, the second one being of a slightly smaller diameter than the first.

The efficiency of a butt weld depends largely upon the relationship of the thickness to the diameter of the tube. The thickness should be sufficient to enable considerable pressure to be put upon the two butting edges without fear of buckling or overlapping of the material, but it must not be so thick that the stress required in putting sufficient pressure on the weld involves a pull on the tube which, after it leaves the ring, may reduce or break it. With the standard thickness of gas, water, and steam

pipe, of the sizes to which this process is usually applied (1/8 to 1½ inches for standard gas, water, and steam thicknesses of these sizes), these conditions are fulfilled, but with heavier pipes it is necessary to effect the welding in several successive passes through graded rings. The production of pipes by butt welding is usually restricted to sizes varying from about ¼ to 2 inches, although pipes as large as 3 inches or even 4 inches have been made in this way. The usual commercial limit, however, is about 2 or 2½ inches. When a very great resistance to inside pressure is required, or when it is essential to use comparatively thin metal, the butt-welding method is impracticable.

By-Pass Valves. When valves are of five or six inches in diameter and upward, and are used for live steam or water under considerable pressure, the type of valve having a by-pass is often used. The object of the by-pass is to equalize the pressure on each side of the valve, so that it can be opened more easily.

C

Cabble. In the making of wrought iron, to cabble is to break up the iron bars into pieces, preparatory to reheating and re-rolling. A "cabbler" is a man engaged in this work.

Cabinet File. A cabinet file is one that is flat on one side and rounded on the other, but which is wider and thinner than a regular half-round file. It is double-cut, with coarse, bastard teeth. This type is made for cabinet makers and wood-workers generally.

Cable. A cable, generally, is a hemp, Manila, or wire rope twisted together from a number of different strands.

Cable, Electric. In electrical engineering, a cable is defined by the Bureau of Standards as (1) a conductor of electric current, composed of a group of wires, usually twisted or braided together; or it may consist of (2) a combination of conductors insulated from one another, generally known as a "multiple-conductor" cable. The component conductors of the second kind of cable may be either solid or stranded, and this cable may or may not have a common insulating covering. The first kind of cable is a single conductor, while the second is a group of several conductors. The term "cable" is applied by some manufacturers to a solid wire heavily insulated and lead covered; this usage arises from the manner of the insulation, but such a conductor is not included under the Bureau of Standards' definition of "cable." Cable is a general term, but, in practice, it is usually applied only to the larger sizes. A small cable is called a "stranded wire" or a "cord." Cables may be bare or insulated, and the latter may be armored with lead, or with steel wires or bands.

A *coaxial cable* is one in which one conductor is a hollow tube and the other is supported by insulators inside the tube and along its axis. This type of cable is used for telephone and television transmission.

Cable-Laid Rope. A cable-laid wire rope is a compound rope consisting of several ropes laid together into one. A cable, for instance, may be made up of six ropes twisted together, each of the six ropes, in turn, consisting of six strands, each of which strands is composed of seven wires. Such a cable-laid rope would be described as a 6 by 6 by 7 rope or cable.

Cadillac Screw Thread. The Cadillac screw thread is so named because it was adopted and used previously by the Cadillac

Motor Car Co. The thread angle is 60 degrees and the top is flat like the American or U. S. standard thread, but the bottom or root of the thread is a sharp V.

Cadmium. Cadmium is one of the metallic chemical elements which shows a close relationship to zinc. Its chemical symbol is Cd, and its atomic weight, 112.4. The specific gravity of the pure metal is 8.56, but the commercial metal has a specific gravity of 8.6, on account of the greater density due to hammering. Cadmium resembles tin in color and general appearance. It does not occur free in nature, but is commonly found associated with zinc in zinc-blende and other zinc ores, and the commercial metal is obtained from the smelting of zinc ores. It is obtained mainly from Silesia and Belgium. Its most important use is in combinations with such metals as lead, tin, and bismuth with which it forms alloys that fuse at very low temperatures. One of these alloys, containing 50 per cent of bismuth, 25 per cent of lead, 12.5 per cent of tin, and 12.5 per cent of cadmium, melts at a temperature of 149 degrees F. Cadmium sulphate is also used for making standard electric cells.

Cadmium Effect on Copper. Copper wire containing a small amount of cadmium has a greater tensile strength and a higher resistance to abrasion than ordinary copper wire, while its electrical conductivity is reduced very little, or less than 1 per cent for each 0.1 per cent of cadmium. The tensile strength increases slowly with increasing cadmium content, until 0.6 per cent of cadmium is reached; beyond this point additions of cadmium cause very rapid increases in tensile strength. Copper wire with 1 per cent of cadmium has been subjected to a temperature of 260 degrees C. for thirty minutes without showing signs of softening. A cadmium-copper wire having 20 per cent greater tensile strength has also 75 per cent greater resistance to breaking after repeated bendings than pure copper wire. In tests made with trolley wires under working conditions, the loss in diameter after eight months' use was less than one-third that recorded for pure copper wire.

Cadmium Solder. Cadmium solders may be used for soldering tin plate, terneplate, brass, and copper, according to an investigation made by the Bureau of Standards. Four different compositions of cadmium solders have been tried: (1) Lead, 90 per cent; cadmium, 10 per cent; (2) lead, 80 per cent; cadmium, 10 per cent; tin, 10 per cent; (3) lead, 85 per cent; cadmium, 10 per cent; tin, 5 per cent; (4) lead, 75 per cent; cadmium, 10 per cent; tin, 15 per cent. The manufacture and use of the alloy first mentioned is rather difficult, because it oxidizes easily in the molten condition. The best composition is said to be that

containing 80 per cent of lead and 10 per cent each of cadmium and tin.

Caesium. A rare, strongly basic metallic element, the chemical symbol of which is Cs, and the atomic weight, 132.8. It melts at 26 degrees C. (79 degrees F.), and has a specific gravity of 1.88. It is silver-white in appearance.

Calcination. The process of calcination is used in metallurgy for expelling, by means of heat, volatile matters with which metals are combined in their ores, thus reducing them, generally, to an oxide. The process is also frequently known as *roasting*. In the metallurgy of many of the most common metals, like copper, calcination or roasting is the first process to which the ore is subjected.

Calcium. Calcium is one of the metallic chemical elements. Its symbol is Ca, and its atomic weight, 40.1. Its specific gravity is 1.57, making its weight per cubic inch 0.057 pound. Calcium melts at a temperature of 810 degrees C. (1490 degrees F.). Its electrical conductivity (silver = 100) is 21.8. Calcium is a metal having a light yellow color and brilliant luster. It is about as hard as gold and is very ductile. It oxidizes rapidly in moist air, and burns at a red heat. A freshly cut surface of the metal closely resembles zinc in appearance, but when tarnished by exposure to the air it becomes yellow, and finally grayish-white. It combines directly with most elements, including nitrogen, and this is taken advantage of in forming an almost perfect vacuum. The metal is generally prepared by electrolysis. The most important industrial use of calcium is in the form of calcium carbide (CaC_2), which is the source of acetylene. Calcium carbide is manufactured by heating lime and carbon in the electric furnace.

Calcium Carbide. Calcium carbide (CaC_2) is a chemical composition of considerable industrial importance on account of the fact that it is used to produce acetylene gas through the action of water upon the carbide, and, hence, it is an important factor in the autogenous welding industry. Calcium carbide is produced in the electric furnace, the raw materials being lime and anthracite in the proportion of 100 parts, by weight, of lime to 68 parts, by weight, of anthracite. About 1.8 pounds of this mixture is required to produce one pound of calcium carbide. Two processes are in use for producing the compound by means of the electric furnace, one being known as the *ingot* process and the other as the *tapping* process.

Calcium Carbonate. This is commonly known as "carbonate of lime," and is found generally in the form of limestone, marble

or chalk. Its specific gravity is 2.8. When contained in the feed water for boilers, it forms a soft mud in the boilers, unless cemented into a scale by the presence of calcium sulphate. It also forms a hard scale in economizers when the water is at a compratively low temperature. It is soluble in water containing carbon dioxide, and is more easily dissolved in cold than in hot water.

Calcium carbonate, also known as *whiting*, is used for paints for the protection of iron and steel against corrosion. It is extensively used in paints, partly because it neutralizes any free acid that may be present in the linseed oil. When produced by artificial means, it generally contains impurities, requires more oil for grinding, and has not a high protective value.

Calcium Chloride. A compound which, when present in boiler feed water, has a corrosive effect and which is one of the causes of *pitting* in boilers.

Calcium Light. A very intense white light produced by two streams of gas, one of oxygen and one of hydrogen, impinged upon lime, while ignited.

Calcium Sulphate. Calcium sulphate, more commonly known as *gypsum* or *plaster-of-paris*, is a sulphate of lime soluble in water free from carbonic acid at moderately low temperatures. When present in boiler feed water, it causes a hard scale difficult to remove. Mixed with mud or the sludge from *calcium carbonate*, it also forms a hard scale. Calcium sulphate is widely used in the making of paints, but its use should be avoided in paints used for the protection of iron and steel against corrosion, because it is somewhat soluble in water and has a tendency to be washed off, and may, for this reason, even promote corrosion.

Calibration. Calibration, in its mechanical sense, denotes an accurate comparison of any measuring instrument with a standard, and more particularly the determination of the errors of a scale used in a measuring device. The method used in calibrating any measuring instrument is generally divisible into two parts, of which one or the other may often be omitted. The first step is to determine the value of the unit to which the measurements are referred, by comparison with a standard unit of the same kind. This part is known as the "standardization" of the instrument, or the determination of a "reduction factor." The second step consists in the verification of the accuracy of the subdivision of the scale of the instrument, which is the actual calibration of the scale, and which does not necessarily involve a comparison of the instrument with any independent standard, but merely a determination of the relative accuracy of the graduations. In many cases, the process of calibration consists of a

comparison of the instrument to be tested with a standard, covering the whole range of the graduations on the standard, the relative values of the subdivisions of the standard itself having been previously tested.

The usual method of calibration is the direct comparison of an instrument with a standard over the whole range of its scale. The standard itself should be previously calibrated so that its accuracy, or the amount of its errors, is known. The term "calibration" refers not only to measurements of length, but to measurements of all other engineering units; thus, for example, ammeters, voltmeters, pyrometers, dynamometers, and all other measuring instruments, are calibrated by a comparison with a standard.

Caliper, Gear Tooth. See Gear Tooth Caliper.

Calipers. Calipers are measuring tools used for taking measurements in machine work, and employed especially for measurements not requiring great accuracy. The ordinary machinist's calipers consist simply of two arms or legs joined with a pivot at one end and provided with points at the other end suitable for the kind of measurement, whether external or internal, that is to be made. Measurements are taken by comparing the caliper setting with the graduations of a scale.

Calite. Calite, an alloy containing iron, chromium, nickel, and aluminum, is the result of experiments conducted by metallurgists of the General Electric Co., for the purpose of finding an alloy that would withstand high temperatures, could be quenched repeatedly, and would be highly resistant to oxidation. Annealing boxes made from calite have been run for 1500 heat-hours with out warpage, growth, or failure. The metal runs freely when molten, and any casting which can be made of steel can also be produced from this alloy. Sections as low as 3/16 inch in thickness have been successfully cast. Calite cannot be machined in the cast condition nor cut with an oxyacetylene torch; hence, it must be finished by grinding.

This alloy is said to resist oxidation up to about 2375 degrees F., but a working temperature of 2200 degrees is recommended. Calite is practically non-corrosive, samples having been polished and subjected to a spray of saturated sea-salt solution at 100 degrees F. for 200 hours without any effect on the polish. The physical properties are: Melting point, 2780 degrees F.; softening temperature, 2500 degrees F.; specific gravity, 7.03; weight per cubic inch, 0.25 pound; and tensile strength, 36,800 pounds per square inch.

Calite Alloys. The Calite alloys are a group of heat-enduring alloys available in the form of castings, sheets, shapes and forgings with particular reference to commercial requirements. Calite

"A" is a nickel-chromium alloy available in cast form only and intended for general heat-enduring applications up to maximum metal temperatures of 2000 degrees F. The metal is readily machinable and entirely resistant to corrosion in contact with the ordinary products of combustion. Calite "B" is a nickel-chromium-aluminum alloy available in cast form only and intended for heat-enduring applications up to maximum metal temperatures of 1800 degrees F. This alloy was developed for the fabrication of beams and other parts required to sustain a load at high temperatures. It is unique in its quality of extreme stiffness at all temperatures up to the maximum safe working limit. The alloy is entirely resistant to corrosion in contact with the ordinary products of combustion. It can not be machined. Calite "E" is a malleable nickel-chromium alloy available in the form of castings, sheets, shapes and forgings. In addition to immunity from oxidation up to maximum metal temperatures of 1800 degrees F., it is not affected by weather corrosion, sulphur compounds and many organic acids and inorganic salts. The alloy finds wide application in sheet form. Sheets may be readily flanged, punched or welded. The welding operation may be successfully performed either with gas or electric arc. Calite "N" is a nickel-chromium alloy available in both cast and rolled form. The alloy is immune to oxidation up to maximum metal temperatures of 2000 degrees F., its chief application being in sheet form. Calite "S" is a malleable chromium-iron alloy available in the form of castings, sheets, shapes and forgings. In addition to immunity from oxidation up to maximum metal temperatures of 1650 degrees F., it is not affected by weather corrosion or by corrosion in contact with nitric acid, sulphur compounds, alkaline solutions and many organic acids. The alloy finds wide application in sheet form.

Calking. The riveted joints of steam boilers and other vessels which subjected to pressure are made tight by "upsetting" and compressing the metal along the edges of the joint, which operation is known as *calking*. The calking tool by means of which the material is compressed is either operated by a pneumatic hammer or, if such a tool is not available, it is struck repeatedly by a hand hammer. As the edge is driven back and upset, the lap extending beyond the rivet is sprung somewhat and reacts against the lower plate with sufficient intensity to prevent the gas or fluid under pressure from passing the calked edge. The calking end of the tool used is rounded, and the radius of curvature should be somewhat proportional to the thickness of the plate to be calked, the radius increasing as the thickness of the plate increases. The edge of a plate that is to be calked should be fairly smooth and even, and should also be slightly

beveled so that the lower edge which is next to the seam projects out somewhat. The angle to which the edge is beveled, varies in different shops, and, in some places, it is gaged merely by the eye, whereas, in others, templets are used. This angle, as measured from the inner or joint side of the sheet, usually varies from 75 to 80 degrees. The heavier form of pneumatic hammers are recommended for calking, in order to secure heavy blows and a more solid connection between the two sheets.

Calorie. The metric unit of quantity of heat, also known as the *French thermal unit,* or the *kilogram-calorie,* is the quantity of heat required to raise the temperature of one kilogram of pure water one degree C. One kilogram-calorie = 3.968 British thermal units. One British thermal unit = 0.252 kilogram-calorie. The British thermal unit (B.T.U.) is the quantity of heat required to raise the temperature of one pound of pure water one degree F.

Calorific Value of Fuel. See Combustion of Coal.

Calorimeters. Calorimeters are of two kinds, fuel calorimeters and steam calorimeters. Fuel calorimeters are used for determining the heating value of fuels. Steam calorimeters are used for determining the percentage of moisture in steam. A *fuel calorimeter* consists mainly of a closed chamber in which a previously weighed sample of the fuel can be rapidly and completely burned. A receptacle containing a predetermined amount of water surrounds this chamber, so that the heat produced by the combustion of the fuel is transferred to the water. A sensitive thermometer is then used for measuring the rise in temperature of the water. Special means must be provided for igniting the fuel, and provision must be made for preventing loss of heat from the calorimeter by radiation or by the escape of the heated gases of combustion. The most commonly used calorimeter is that known as a "bomb calorimeter," also called "Mahler's modification of Berthelot's calorimeter."

Steam calorimeters are constructed in a number of different ways; one of those most commonly used consists of a half-inch pipe closed at one end and perforated with several 1/8-inch holes in its walls. This pipe is inserted into the main steam pipe so that the steam can enter through the small holes. The other end of the pipe is throttled by an orifice 1/16 inch in diameter, through which the steam escapes into a chamber having an outlet to the atmosphere. The temperature and pressure of the steam on each side of the orifice are then observed. The action of the instrument depends upon the fact that the heat of saturated steam increases with the pressure, and, consequently, if the pressure is reduced by the throttling effect of the orifice, the

heat liberated will convert the moisture into steam and produce super-heating. The steam in the chamber mentioned is super-heated according to the amount of moisture contained in the steam passing into the half-inch pipe from the main steam pipe.

Calorimetric Pyrometers. In calorimetric pyrometers, the total heat absorbed by a metal—platinum, in the laboratory, and nickel or copper, in industrial works—is used to indicate the temperature. This was an early form of pyrometer.

Calorizing. Calorizing is a process for covering metals with a layer of alumina, so that the metal can be heated to a comparatively high temperature—dull red heat—without oxidizing and deteriorating. Calorizing is used, among other things, for copper soldering irons, and for iron resistance wires for electric heating devices. It is intended only for protection at high temperatures and does not take the place of galvanizing, sherardizing, or similar processes for the protection of iron against oxygen or corrosion at low temperatures. Its usefulness lies within a range of temperatures which are much higher than those to which a galvanized or sherardized coating could be exposed.

Camelia Metal. A bearing metal composed of 70 per cent of copper, 15 per cent of lead, 10 per cent of zinc, 4.5 per cent of tin, and 0.5 per cent of iron is known as "Camelia" metal. It belongs in the same class as Ajax plastic bronze and brasses used for railroad car bearings.

Camograph. "Camograph" is the trade name given to one type of machine for mechanically guiding an oxy-acetylene cutting torch. This machine is intended for use in boiler shops and fabricating plants, to provide a means of cutting hand-holes and other openings in boiler sheets, ship plates, tanks, drums, etc. Provision may be made for cutting various shaped openings by substituting the proper cams on the machine.

Cams. Many machine parts require either an intermittent or an irregular motion. The most common method of obtaining an irregular motion is by means of cams which have grooves or surfaces of such shape or form that the required motion is imparted to the driven member when the cam is in motion. The exact movement derived from any cam depends upon the shape of its operating groove or edge, which may be designed according to the motion required.

Cams may be classified according to the relative movements of the cam and follower and also according to the motion of the follower itself. In one general class may be included those cams which move or revolve either in the same plane as the follower or a parallel plane, and in a second general class, those cams which

cause the follower to move in a different plane which ordinarily is perpendicular to the plane of the motion of the cam. The follower of a cam belonging to either class may either move in a straight line or receive a swinging motion about a shaft or bearing. The follower may also have either a uniform motion or a uniformly accelerated motion.

The working edge or groove of a uniform motion cam is so shaped that the follower moves at the same velocity from the beginning to the end of the stroke. Such cams are only adapted to comparatively slow speeds, owing to the shock resulting from the sudden movement of the follower at the beginning of the stroke and the abrupt way in which the motion is stopped at the end of the stroke. If the cam is to rotate quite rapidly, the speed of the follower should be slow at first and be accelerated at a uniform rate until the maximum speed is attained, after which the motion of the follower should be uniformly decreased until motion ceases, or a reversal takes place; such cams are known as "uniformly accelerated motion cams."

Types of Cams: Cams may be divided, according to their mechanical construction, into three different types—plate cams, face cams, and cylinder cams. *Plate cams,* also known as *disk* or *peripheral cams,* are those cams which consist of a flat disk, and on which the follower operates against the outside or peripheral surface of the disk. A well-known type of this form is the *heart cam,* so called because of its peculiar shape. The *face cam* also consists of a flat disk, but the follower, instead of operating against the outside periphery of the disk, engages a groove cut into the flat surfaces of the cam. *Cylinder cams,* also known as *barrel cams,* are cylindrical in shape; the follower engages a groove cut into the cylindrical surface of the cam. Either of these types of cams may be designed to produce a uniform or a uniformly accelerated motion, or may produce any irregular motion required. The type of cam, as regards uniformity of motion, depends upon the dynamic conditions; but the form of cam, whether a plate cam, face cam, or cylinder cam, depends entirely upon the designer's judgment as to the best mechanical means of obtaining the desired movement. See Gravity Curve; Harmonic Motion Curve.

Cams, Grinding. The cams used on gas and gasoline motors, for operating the inlet and exhaust valves, are finished to the correct form by grinding. This grinding may be done in a regular cylindrical grinding machine by using a suitable cam-grinding attachment. The general method of grinding cams is by so mounting the cam or camshaft that, while rotating, it will be moved toward and from the grinding wheel by a master cam, the movement causing the cam to be ground to the required

form or contour. The master cam is in engagement with a roller which transmits motion to the work-holding fixture. It is evident that cam grinding first involves the generation of master cams, since these must be made to suit each different form of cam that is ground.

Cams, Milling. Most cams are milled by using either an attachment on a milling machine or a special cam-cutting machine, the arrangement in either case being such that the contour of a master cam or templet serves to control the curvature of the cam groove that is milled. The curvature of the master cam groove or templet may or may not be an exact duplicate of the cam that is cut, as this depends upon the design of the cam-cutting mechanism.

Cam Milling Machine: Cam or form milling machines operate on the same general principle as an ordinary profiling machine, although the construction is different. When a machine of this type is in operation, a pen or roller bears against a former plate or model, and, as the work table revolves, the cutter is caused to move so as to reproduce the required outline on the work. The master cam is rotated in whichever direction presents the least abrupt angles for the roller and cutter to pass over. For instance, if a cam were being milled having a sudden rise at one point, the direction of rotation should be such that the former pin will approach the rise from that side which has the most gradual ascent.

Canadian Corundum. A natural abrasive containing from 90 to 95 per cent of crystalline alumina, which constitutes the cutting material of the abrasive. As an abrasive it is much better than emery, containing less iron oxide, which is the most objectionable impurity. Canadian corundum is mined in eastern Ontario, where there are very large and practically inexhaustible deposits.

Candlepower. The lighting effect of a source of light is measured or expressed in candlepower. A "candle" is the unit of light intensity. The unit used in the United States is a specified fraction of the average horizontal candlepower of a group of 45 carbon-filament lamps preserved at the Bureau of Standards, when the lamps are operated at specified voltages. This unit is identical, within the limits of uncertainty of measurement, with the International Candle established in 1909 by agreement between the national standardizing laboratories of France, Great Britain, and the United States, and adopted in 1921 by the International Commission on Illumination.

The maintenance of the adopted unit by means of incandescent lamps is a temporary expedient, pending the development of a

satisfactory reproducible primary standard. It is expected that eventually the unit will be defined as a fraction of the luminous intensity of a black-body radiator under specified conditions.

Distinction is made between the *mean horizontal candlepower* of a lamp, which is the average candlepower in a horizontal plane passing through the luminous center of the lamp when mounted in the usual manner, as, for example, in the case of an incandescent lamp with its axis of symmetry vertical; the *mean spherical candlepower* of a lamp, which is the average candlepower of the lamp in all directions; and the *mean hemispherical candlepower* of a lamp, which is the average candlepower of the lamp in either the upper or the lower hemisphere.

One candle will produce an illumination of one *foot-candle* on a surface which is one foot normal distance away.

Cannonite. Low-carbon chromium alloy having a higher tensile strength than ordinary cast iron and possessing exceptional wearing qualities. For sand-casting automobile brake-drums and centrifugally casting cylinder sleeves.

Cant-File. Cant-files and cant-saw files are files of triangular cross-section, and differ in cross-section as to their angles; the cant-file has 30, 30, and 120 degree angles and the cant-saw, 35, 35, and 110 degree angles. The cant-saw shape was formerly known as "lightening." It is used principally for filing cross-cut saws having N-shaped teeth.

Cantilever. A cantilever is a beam which is supported or held firmly at one end and which projects from its support so that the outer end is free and unsupported. Each half of a cantilever bridge, for example, is wholly supported from the abutments and towers at the ends of the span, and the arms that reach out from the towers do not, in any way, depend upon their connection with each other at the center to increase their carrying capacity. They are merely connected, but each arm or cantilever is so proportioned that it is able to carry the load on the bridge independently of the remainder of the structure.

Capacitance. The capacity or capacitance of an alternating electric circuit is the measure of the amount of electricity held by it when its terminals are at unit potential. A condenser is said to have unit capacity if unit current existing for one second produces unit difference of potential at its terminals. The practical unit of capacity is that of a condenser in which one ampere during one second produces one volt difference of potential; it is called a *farad.* One farad is an extremely large capacity, and, therefore, one-millionth of one farad, called *micro-farad,* is commonly used. The effect of capacity is directly opposite to self-induction.

Capacity. The expression "capacity" is used in a number of different meanings in science and engineering. The capacity for heat is the amount of heat required to raise the temperature of an object one degree; hence, the capacity for heat is equal to the product of the mass or weight of an object by its specific heat. Sometimes the capacity for heat is expressed in terms of the amount of water which would be raised one degree by the amount of heat in question.

The capacity of an air compressor equals the amount of *free air* in cubic feet which may be compressed to a given higher temperature in a unit of time.

In electrical engineering, capacity is used in the terms *power capacity* and *current capacity*, referring to the power or the current which a device can safely carry. The temperature rise in a conductor due to heat developed when an electric current flows through it, is one of the limiting factors of the current-carrying capacity of a conductor.

Capacity is also used when referring to the electrostatic capacity of a device, but it has been recommended by the American Institute of Electrical Engineers that, when used in this sense, the term *capacitance* be used instead. See also Capacitance.

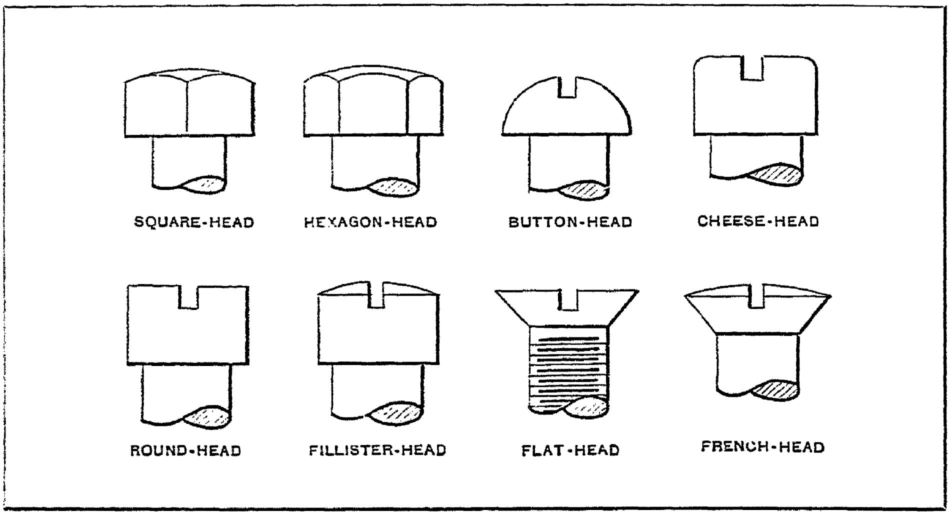
Cape Chisel. A form of cold chisel having a narrow blade for the cutting of grooves or keyways. See Cold Chisels for illustration.

Capillary Action. When a tube of glass, the bore of which is very small in diameter and which is open at both ends, is placed vertically with its lower end immersed in water, the water will rise in the tube and will reach a higher level on the inside of the tube than the level of the water outside. The force or action which makes the water rise higher inside of the small-diameter tube is known as "capillary action." The same name is used for many other phenomena observed in the properties of liquids when spread over surfaces. Capillary actions are explained by reference to surface tension, cohesion, and adhesion between the molecules, etc. Capillary action is of importance in many devices used for lubrication, the oil rising against gravity along a wick and thereby reaching the surface to be lubricated.

Cap-Screws. Cap-screws usually are inserted into tapped holes like machine screws, but they are made in larger sizes and generally are used for heavier work. American standard hexagonal cap screws range in diameter from 1/4 inch to 1 1/4 inches. Flat-head and button-head cap-screws range in diameter from 1/4 to 3/4 inch. Fillister-head cap-screws range from 1/4 to 1 inch. The accompanying illustration shows some standard and special forms of heads. American standard cap-screws regularly are

threaded to the coarse series of pitches. The thread length for the coarse thread series equals twice the diameter plus 1/4 inch. The thread length for the fine series, according to the S.A.E. standard, equals one and one-half times the diameter plus 1/4 inch. Cap-screws that are shorter than the thread length obtained by these diameters are threaded as close to the head as practicable.

Capstan Lathe. In England, turret lathes are often called *capstan lathes.* The terms *"capstan"* and *"turret,"* however, are sometimes used interchangeably, although many firms observe a sharp distinction in their application, in that they apply the name "capstan" only to those machines which have a slide moving in



Names of Cap-screws

a saddle that is bolted down to the bed, whereas the name "turret" is used when the turret-slide is mounted directly on the bed. The effective difference between the two designs is that the working stroke of the first one is limited by the movement of the turret-slide in the saddle, whereas, with the second arrangement, the longitudinal feeding movement of the turret is limited by the length of the bed. See Turret Lathe Classification.

Carat. In reference to gold, a carat is an indication of how many 24ths of an alloy is pure gold. For example, 18-carat gold is an alloy containing 18/24 pure gold and 6/24 of other alloying metals. A carat is also a unit of weight used for diamonds and precious stones. The international carat, adopted 1905, and since then made standard in most European countries and, on July 1, 1913, in the United States, equals 200 milligrams or 3.086 grains

troy. The South African carat is 3.174 grains. The old carat, standardized in 1877, was 205 milligrams or 3.163 grains troy.

Carbide Generator. See Water-carbide Generator.

Carbide Metal-Cutting Tools. Metal-cutting tools made of cemented or sintered carbides are used in various branches of the machine-building industry either because of the exceptionally high cutting speeds that are possible with these tools, or because of their durability and adaptability in machining either very hard materials or compositions that are destructive to other tools. Cemented carbide is the hardest metallic tool material known. The harder grades are about three times as hard as hardened tool steel.

Sintered carbides are made in a number of different grades (with different combinations of hardness and toughness) to adapt them to the cutting of a large variety of materials. For example, tungsten carbides are especially adapted to cutting cast iron and there are other grades that are more effective as applied to steel. These steel-cutting carbides contain tantalum or titanium carbide, thus changing the properties of the carbide so as to resist the seizing action of the steel chips and prevent formation of a chip cavity back of the cutting edge. When ordinary cemented tungsten-carbide tools suitable for cast iron are used for steel, the formation of these chip cavities shortens the life of the tool and increases the time required for grinding. Information about the particular grade or type of carbide tool for cutting a given material should be obtained directly from the manufacturers. These different grades are designated by various trade names and symbols.

In general, carbide tools are not only very effective in machining all classes of iron and steel, but they are also applicable to non-ferrous alloys such as brass, bronze, and aluminum; to hard rubber, fiber, non-metallic materials for gears, etc.; slate, marble, and other materials which are either too hard for steel or which would quickly dull steel tools by their abrasive action. Sintered or cemented carbides are now applied to various types of tools for turning, milling, reaming, drilling, etc.

Carbide of Silicon. A compound of silicon and carbide having the chemical formula SiC. See Abrasives.

Carbolite. The trade name "Carbolite" is used by the American Emery Wheel Works for silicon-carbide products. See Silicon Carbide.

Carbolon. The trade name "Carbolon" is used by the Exolon Company for silicon-carbide products. See Silicon Carbide.

Carbon. In nature, carbon is found free in two forms, as the diamond and as graphite; in combination with other elements carbon enters as a constituent of practically all animal and vegetable compounds, and of coal and petroleum. The specific gravity of carbon in the form of diamond is 3.5. When found as graphite, the specific gravity is about 2. Charcoal is also a porous form of nearly pure carbon. The properties of carbon vary according to the form in which it is found; thus, for example, the specific heat of diamond at 10 degrees C. (50 degrees F.) is about 0.11; of graphite at the same temperature it is about 0.16; and of wood-charcoal, 0.17. Besides the industrial uses of carbon in the form of graphite and charcoal, it is the chief constituent of all combustible materials, and is one of the most important of the chemical elements in its combination with other elements. The carbon content of steel, for example, determines to a very large extent its characteristics. In fact, the distinction between wrought iron, mild steel, tool steel, and cast iron is due mainly to the different percentages of carbon contained in the metal.

Carbonate of Lime. Same as *calcium carbonate.*

Carbonate of Soda. Same as *sodium carbonate.*

Carbon-Break Circuit-Breaker. A device for automatically opening an electric circuit, so arranged that the arc is broken in the air between carbon blocks, although when closed most of the current is carried through copper contacts. Carbon is used because it withstands the heat of the arc without being destroyed, and the carbon contacts will not "freeze" together. Most air breakers are of this type.

Carbon Dioxide. A compound of carbon and oxygen, the chemical formula of which is CO_2.

Carbonia Finish. A carbonia finish consists of a method of coloring iron and steel surfaces with any of the temper colors that are obtainable by heating steel to different temperatures. The operation is carried out in a rotary gas furnace; the finish produced has a high luster.

Carbonic Acid. Same as *carbon dioxide.*

Carbonite. The trade name "Carbonite" is used by the General Abrasive Company for silicon-carbide products. See Silicon Carbide.

Carbonizing. A term often applied erroneously to carburizing. See Carburizing.

Carbon Resistor. Carbon resistors may be of the fixed or variable type. The latter, called rheostats, are composed of a number of carbon plates or granules to which varying degrees of

pressure may be applied by turning a control dial or knob. Increased pressure on the carbon pile produces a greater number of contacts between the carbon particles and the total resistance of the rheostat is reduced. When pressure is reduced the opposite effect is obtained. Such rheostats provide almost stepless control, high overload capacity and a wide control range.

Carbon Steel. The expression "carbon steel" is often applied to tool steel containing no alloying metals, the term being used to distinguish such steel from alloy steels which contain tungsten, nickel, chromium, or other metals. These alloy steels also contain carbon and many to the same extent as "carbon steel"; hence, this expression is not strictly correct in a chemical or metallurgical sense. The carbon content in steel is generally expressed by giving the percentage of carbon as, for example, 0.90 per cent carbon steel. This is also often expressed as "90-point" carbon steel.

Carbon "Points" in Steel: The point system used in specifying the carbon content of steel is based on the division of one per cent into one hundred parts; hence, "10 points carbon" means one-tenth of one per cent carbon and not 10 per cent. To express the carbon content in percentage in the case, say, of 50-point carbon steel, the expression should be "one-half per cent" carbon. The term "points" probably originated in an inversion of the reading of the decimal of one per cent; the decimal 0.40, for instance, was read "40-point" instead of "point 40" in order to emphasize.

Carbon Temper of Steel: The carbon temper of steel is a term applied by steel makers to indicate the proportion of carbon in the steel, the temper marks or numbers being arbitrarily selected so that their relation to the percentage of carbon varies with different makers. According to one system, the temper number indicates approximately the number of tenths of the carbon percentage; for example, No. 8 carbon temper designates steel containing about 0.80 per cent of carbon, while No. 14 carbon temper designates steel containing about 1.4 per cent of carbon.

Carbon Steel Heat-Treatment. See Heat-treatment of Carbon steel.

Carbon Temper. See under Carbon Steel.

Carbon Tool Steel Applications. Steel with a carbon content of from 0.65 to 0.80 per cent is suitable for shear blades, boiler snaps, and cups, hammers, stamping and pressing dies, and mining drills. Steel with a carbon content of from 0.81 to 0.95 per cent is suitable for hot and cold sets, chisels, dies, shear blades, mining drills, blacksmiths' tools, swages, flatteners, and set-hammers. Steel with a carbon content of from 0.96 to 1.10 per cent is suitable for small cold chisels, hot sets, small shear blades, large pincers, large taps, granite drills, trimming dies, turning

tools, planer tools, drills, cutters, slotting and milling tools, mill picks, circular cutters, small shear blades, and threading dies. Steel with a carbon content of from 1.11 to 1.25 per cent is suitable for small milling cutters, small taps, drills, slotting and planing tools, wood-cutting tools, turning tools, and razors.

The best all-around tool steel contains from 0.90 to 1.10 per cent of carbon, and can be adapted to a wider range of uses than any other grade. For tools, generally, it gives the highest strength together with a high degree of hardness when heat-treated. It cannot, however, be welded easily. Steels containing up to 1.50 per cent of carbon are easily burnt, and are welded only with great difficulty. They can, however, be hardened to an extreme hardness.

Carborite. The trade name "Carborite" is used by the Vitrified Wheel Company for silicon-carbide products. See Silicon Carbide.

Carborundum. "Carborundum," is the registered trade-mark of The Carborundum Company covering silicon carbide and other abrasive products made by it. This term is not properly used as a generic name for silicon carbide.

Carbowalt. The trade name "Carbowalt" is used by the Waltham Grinding Wheel Company for silicon-carbide products. See Silicon Carbide.

Carburetor. The purpose of the carburetor of a gasoline engine is to introduce into the current of air, entering the cylinder of the engine, a proper quantity of gasoline in such a manner that it will be completely evaporated and thoroughly mixed with the air. The devices for forming an explosive mixture from gasoline and air may be divided into two distinct groups. In the *spraying* or *atomizing* type of carburetor, which is used on gasoline engines for automobiles, motor boats, etc., the necessary quantity of gasoline for each charge of the engine is atomized by a valve and then sprayed into the inrushing air, which process, especially when the air has previously been heated, is so thorough that the mixture may be used immediately for charging the engine. In the *vaporizing* carburetor, which is the type largely used for stationary engines, the engine piston draws air directly through a gasoline storage tank, thus saturating it with gasoline vapor. Additional air must be drawn in before the vapor enters the engine cylinders, to form an explosive mixture.

Carburizers. Carburizers may be classed by their physical form as follows: (1) Powder materials, in which the generator and the energizer are in a powder form and are thus mixed together. (2) Pill materials, in which the generator and the energizer are in a powder form, but are held together by a binder

which in itself may be either a generator or an energizer. (3) Pellet materials, in which the generator is a granule of solid carbonaceous material coated with an energizer by the help of a binder. (4) Pellet and powder materials, in which the generator is a granule of solid carbonaceous material, and the energizer is in the form of a powder. A certain per cent of the powder may also be a generator. Different combinations of the above four forms may be found, but no great value should be attached to claims for their importance. Two other mediums are still used to some extent for carburizing, namely, bone and leather. Bone is classed as a pellet material, with the exception that the energizer is contained in the bone in the form of ammonium carbonate. The ammonia fumes are quite noticeable when water is poured on red hot bone. Leather is classed as a powder material due to its being so easily powdered. The energizer is in the form of cyanogen and is contained within the leather. Charcoal, coke and coal should not be classed as carburizers, as they are nothing more than generators. Alone, they are not easily controlled as regards penetration and percentages of carbon entering the steel to form the case. There are many commercial carburizers on the market in which the materials used as the generator may be hard and soft wood charcoal, animal charcoal, coke, coal, beans and nuts, bone and leather, or various combinations of these. The energizers may be barium, cyanogen, and ammonium compounds, various salts, soda ash, or lime and oil hydrocarbons. Sulphur and phosphorus are the two impurities that cause the greatest trouble in carburizing and are therefore the greatest drawbacks.

Carburizing. Carburizing, often erroneously known as "carbonizing," is generally referred to in connection with casehardening of steel. Carburizing consists in adding carbon to the surface of low-carbon steel by heating the steel in contact with materials high in carbon. The steel absorbs a certain amount of carbon from the carbonaceous materials, and this increase in the carbon content of the surface of the steel makes it possible to harden the steel in a manner similar to that in which so-called "high-carbon" steel is hardened, that is, by heating to a red heat and cooling by quenching.

To harden low-carbon steel involves two separate operations: First, the carburizing operation for impregnating the outer surface with sufficient carbon, and second, the heat-treating of the carburized parts so as to obtain a hard outer case and, at the same time, give the "core" the required physical properties. The term *casehardening* is ordinarily used to indicate the complete process of carburizing and hardening, but it is often applied to indicate the heat-treatment after carburization.

Carburizing by Rotary Method. In carburizing by the rotary method, the work is contained in a slowly revolving retort, where it is heated and subjected to the action either of a carburizing gas or of a solid carburizer. The parts, when sufficiently heated, have an affinity for the carbon in the gas or in the carburizing material, as the case may be, and the slow rotation which exposes all surfaces, combined with accurate temperature regulation, insures uniform carbon penetration and comparatively rapid action. When a carburizing machine is supplied with the proper air and fuel conditions, its charge may be brought to a carburizing heat of 1650 degrees F. in from three-fourths to one hour's time, depending upon the size of the work. Actually carburization starts about the time the work reaches a low red heat. If heat controllers are used, it is customary and practical to start the computation of carbon penetration at the time that the heat controllers shut off the fuel.

The fuel ordinarily used for heating the work is gas, but oil may also be employed as the heating fuel. Gas is preferable, as it is cleaner, requires practically no burner attention, and auxiliary equipment, such as heat-controlling apparatus, storage facilities, etc., is less complicated and less expensive. Gas is also more flexible in regard to temperature variations. The oil-fired machines are satisfactory, but much depends upon the manipulation of the burners. As one of the primary agents in gas for carburizing is the illuminants, and as these illuminants vary with the manufacture of gas, it is often found that the best results are obtained from solid carburizers. Any carburizing agent that is suitable for pack-hardening is satisfactory. Oil hydro-carbon materials may be objectionable on account of the smoke. Barium energized materials, and those containing less than 3 per cent sodium carbonate, are desirable. A powder material carburizes as fast as the same material in pill form.

Card Pattern. A molding pattern with a number of individual patterns gated together so that several can be molded at once.

Card-Weight Pipe. A term used to designate standard or full-weight pipe, which has the standard thickness.

Carnot's Function. In thermo-dynamics, that function of temperature in Carnot's theory of heat which corresponds to the reciprocal of the absolute temperature.

Carriage Bolt. A bolt having an oval head in cross-section, beneath which the bolt is square for a short distance. The other end of the bolt is threaded for about twice its diameter for a square nut.

Cartridge Brass. The sheet brass used for making cartridge cases for rifles and other small arms has, according to A.S.T.M. Specifications B19-29, the following composition, in per cent: Copper, 68 to 71; lead, 0.07 max.; iron, 0.05 max.; other materials, 0.15 max.; zinc, remainder.

Cartridge Fuse. A cartridge fuse consists essentially of one or more strips of fusible metal enclosed in a fiber tube filled with a powdered insulating substance. This substance serves to absorb the heat liberated when the fuse is blown and condenses the vapor of the molten metal, breaking the continuity of the electric circuit.

Car-Wheel Boring Machines. The purpose for which boring machines of this type are intended is indicated by the name. There is a single vertical spindle located in alignment with the center of the circular work table, which has chuck jaws for holding the car wheels while boring them. The spindle is counterweighted either by a wire cable and weight or by a pivoted lever attached to the upper end and having an enlarged outer end the same as the counterweight of a slotter. These machines are sometimes equipped with a horizontal slide for facing the wheel hubs. They are very efficient for the limited class of work to which they may be applied.

Car-Wheel Grinding. Car wheels in general have soft iron centers with deeply chilled treads. It is economy to grind new wheels to prevent difficulties that arise from wheels slightly out of round. Used wheels that have developed flat spots are economically salvaged by grinding. On one make of car wheel grinding machine, grinding wheels 24 inches in diameter by 4 inches thick are employed. The work in this case is not traversed but the grinding wheel is fed straight in, so that the entire surface of the tread is ground with the full width of the grinding wheel. The car wheels are usually not removed from their axles before grinding. During the grinding the car axles revolve on their journals rather than on centers. On this account some vibration takes place which tends to disintegrate the wheel structure, and this together with the very great pressures applied to hasten the grinding necessitates the use of very hard wheels.

Casehardening. In order to harden low-carbon steel it is necessary to increase the carbon content of the surface of the steel so that a thin outer "case" can be hardened by heating the steel to the hardening temperature and then quenching it. The process, therefore, involves two separate operations. The first is the *carburizing* operation for impregnating the outer surface with sufficient carbon, and the second operation is that of heat-

treating the carburized parts so as to obtain a hard outer case and, at the same time, give the "core" the required physical properties. The term "casehardening" is ordinarily used to indicate the complete process of carburizing and hardening, but it is often applied to indicate the heat-treatment after carburization.

For certain uses, steel parts are required to resist wear and at the same time to be sufficiently tough to withstand shocks. Toughness and hardness, however, are two qualities which do not appear at their maximum at the same time in steel. In machine construction, articles which must have a perfectly hard surface, and yet be of such internal structure that there is no chance of their breaking when in use, can be made to greater advantage from a mild steel which is casehardened than by using an expensive high-class crucible steel.

Casehardening Process: In general, the casehardening process consists of packing steel articles made from a low-carbon steel in metal boxes or pots, with a carbonaceous compound surrounding the steel objects. The boxes or pots are sealed and placed in a carburizing oven or furnace maintained at a heat of from about 1650 to 1830 degrees F. for a length of time depending upon the extent of the carburizing action desired. The carbon from the carburizing compound will then be absorbed by the steel on the surfaces desired, and the low-carbon steel is converted into high-carbon steel at these portions, while the internal sections and the insulated parts of the object retain practically their original low-carbon content. The result is a steel of a dual structure, a high-carbon and a low-carbon steel in the same piece. The carburized steel may now be heat-treated by heating and quenching, in much the same way as high-carbon steel is hardened, in order to develop the properties of hardness and toughness; but as the steel is, in reality, two steels in one, one high-carbon and one low-carbon, the correct heat-treatment after carburizing includes two distinct processes, one suitable for the high-carbon portion or the "case," as it is generally termed, and one suitable for the low-carbon portion or core.

Rehardening: The method of heat-treatment varies according to the kind of steel used. In general, quenching from the pot and again rehardening at a temperature of from 1400 to 1450 degrees F. will serve the purpose of refining the case to a great extent and will likewise bring out the natural qualities and toughness of the initial steel or core. Cooling in the pot, rehardening at about the critical temperature of the core, and quenching (the critical temperature being from about 1550 to 1650 degrees F., depending upon the original carbon content of the steel), and rehardening at the critical temperature of the case (1400 to 1450 degrees F.) will serve to refine the core and case to the

maximum extent. The result will be maximum toughness and grain refinement of core, and maximum toughness, grain refinement, and hardness of the case. The function of cooling in the pot is to allow the structure of the steel to come to rest, which helps to prevent warpage from internal strains.

Cyanide Bath: Another method of casehardening is to immerse steel articles in a cyanide bath heated to about 1580 degrees F. This process is convenient and effective only on small articles and where the required depth is not more than from 0.005 to 0.015 inch, or where a mere surface hardening is wanted. This is a fast case-forming method, being accomplished in from ten to fifteen minutes. The outstanding disadvantage of this process is the impossibility of producing uniform cases. The parts that are deep in the melted bath do not receive the same depth of penetration as the parts near the surface because the evolution of the cyanide gases at or near the surface favors penetration.

Cyanide Process: Casehardening may be done either by dipping a cherry-red piece of steel or tool into a container of powdered cyanide salt, such as potassium cyanide, sodium cyanide, or ferro- and ferri-cyanides, or sprinkling the powdered salt on the red-hot steel surface, and putting the steel back in the fire. The casehardening produced in this way is superficial, and resistance to excessive wear cannot be expected.

Gas Process: In another method, carburizing gases are passed over a piece of steel heated in a retort. This process is applicable to parts that are intricate in design. The principle upon which this process is based is the casehardening of steel and iron-alloy articles in cyanogen gas evolved from a container filled with an alkali cyanide salt, heated by electrical energy or other means to accomplish the vaporization or boiling of the salt. The parts being treated are independently heated out of contact with the fused cyanide salt. The depth of penetration is a function of the uniformity of the temperature of the article treated and the duration of treatment. Nascent cyanogen gas has a speed of penetration of four or five times that of carbon monoxide. Sodium cyanide melts at 1112 degrees F. and boils at 1472 degrees F. Thus, the temperature of the pot must not be less than the latter, and to absorb this gas effectively, the steel must be at a temperature above the upper critical point, or about 1650 degrees F. See Nitrogen Hardening.

Casehardening Carburizers. See Carburizers.

Casehardening Steel. A low-carbon steel containing, say, from 0.15 to 0.20 per cent of carbon is suitable for casehardening. In addition to straight carbon steels, the low-carbon alloy steels

are employed. They add to the parts the same advantageous properties for which they are employed in other classes of steel. *Nickel* is a valuable aid in producing a core which readily responds to refining and at considerably lower heats than in steel in which it is absent. In some cases results have been obtained by a single heat-treatment which compare most favorably with straight carbon steel, given two heats, one for case and one for core. The core resulting has a fine grain and is extremely tough. *Chromium* gives a very fine grain to case and core and imparts additional hardness in conjunction with the carbon. It has, however, when present in an amount much over 0.25 per cent, a tendency to render the core less tough, especially in steels around 0.20 per cent carbon, or higher. *Chrome-nickel* steels containing both of these elements give very good results. They give very fine-grained parts after heat-treatment, and can be treated at a considerably lower temperature than straight carbon steels.

Casein Glue. See Glues for Wood.

Casing Thread. The standard casing thread of the American Petroleum Institute is the same in form as the American Standard Pipe Thread. The included angle is 60 degrees and the thread depth equals 0.8 times pitch; hence, the thread is truncated with flats at crest and root. The ten nominal casing sizes range from 4¾ inches to 24½ inches. The 4¾-, 5¾-, and 8⅛-inch sizes have ten threads per inch. (The 8⅛-inch size is "inactive" and available on special order only.) The 7⅝-, 10¾-, 13⅜-, 16-, 18⅝-, 21½-, and 24½-inch sizes all have eight threads per inch. The taper is ⅜ inch per foot whenever there are ten threads per inch and ¾ inch per foot for eight threads per inch.

Casing Thread, Oil-Well. See Oil-well Casing Thread.

Casting. In casting, a part is formed either by pouring molten metal into a mold, as in making ordinary iron, steel or brass castings, or by forcing molten metal under pressure into a mold or die as in die-casting. The term "casting" is applied both to the process and to the parts produced by it. See Aluminum Castings; Brass Alloys for Castings; Gear Castings, Bronze; Cast Iron; Chilled Castings; Cold-pressed Castings; Copper Castings; Malleable Castings; Steel Castings.

Casting, Centrifugal. See Centrifugal Casting.

Casting in Permanent Molds. A method for making castings by the use of what is termed permanent molds, is known as the *Custer process.* The molds are made of metal, and, hence, of a permanent nature, as compared with sand molds which disintegrate after each casting is made. The permanent molds should be made of a soft cast iron fairly high in silicon and graphite

carbon, and low in combined carbon. A cast iron used for permanent molds is as follows: Combined carbon, 0.84 per cent; graphite carbon, 2.76 per cent; silicon, 2.02 per cent; sulphur, 0.07 per cent; phosphorus, 0.89 per cent; and manganese, 0.29 per cent.

The reason that it is possible to produce soft castings in a permanent metal mold is due to the fact that a certain time elapses between the point at which the molten metal will set and the temperature at which it will begin to chill. This interval is long enough to give the operator of the mold time to remove the casting from the mold before chilling begins. At this time the casting is still at a bright red heat, but the sudden contact with the cool surfaces of the mold has made the surface of the casting sufficiently hard so that it can be handled without fear of distortion or breakage.

"Casting-on" or "Burning-on." See "Burning-on" or "Casting-on."

Cast Iron. According to the specifications adopted by the International Association for Testing Materials, *cast iron* is defined as iron containing so much carbon that it is not malleable at any temperature. To conform to this definition, iron containing more than 2.2 per cent of carbon is classified as cast iron. Generally, commercial cast iron, however, has a carbon content of between 3 and 4 per cent. This carbon may be present as graphite, in which case the iron is known as *gray cast iron,* or it may be present in the form of cementite or combined carbon, in which case the iron is known as *white cast iron.* In most cases, however, carbon is present partly as graphite and partly as cementite. Besides carbon, silicon, sulphur, manganese, and phosphorus are nearly always present in cast iron. Cast iron is almost universally used for forms that must be shaped by casting, especially where weight is not objectionable, or where considerable weight is desired. Ordinary cast iron should not be used for parts which are subject to shock or strain, as it is weak in tension and brittle. Cast iron makes a good bearing surface and is cheap. Surfaces of cast iron parts which are subject to continuous wear will last much longer if they are chilled.

Graphite Carbon: Graphite is merely mixed with the iron instead of being in chemical combination. Since it is only mixed with the metal, it cannot exert any direct influence upon the properties of the molecules of the iron. So far as the graphite itself is concerned, the toughness, hardness, and melting point of the grains of the iron will not be altered. The tensile strength will, however, be greatly affected, since the interposition of the flakes of graphite will act as partings between the grains of the

metal and reduce the cohesion. Iron high in graphite is soft, and can be machined readily, but it is of low tensile strength.

Combined Carbon: The carbon which is in chemical combination affects directly and greatly the properties of ordinary cast iron. It is the principal factor in determining the hardness, tenacity, soundness, and freedom from internal stresses of the castings. In general, the percentage of combined carbon ranges from 0.05 in the softest cast iron to about 0.60 in iron of the highest strength. With suitable iron mixtures, the amount of silicon and sulphur present regulates the separation of carbon as graphite, so that the amount of silicon present is an index of the relation between the free and combined carbon. When the graphitic carbon is in excess, the fracture is grayish in color and the iron is known as *gray iron.* When the combined carbon is in excess, the fracture is either mottled or white, and is known as either mottled or *white iron.*

Cast Iron Properties: Ordinary cast iron generally is assumed to have an ultimate tensile strength of 18,000 to 22,000 pounds per square inch, an ultimate compressive strength of 80,000 to 100,000 pounds per square inch, an ultimate shearing strength of 18,000 to 25,000 pounds per square inch, and a modulus of elasticity of 12,000,000 to 16,000,000. Cast iron retains its strength of 100 per cent up to 400 degrees F., but falls from this point to 92 per cent at 750 degrees F. and 42 per cent at 1100 degrees F. The strength begins to decrease at about 500 degrees F. The specific gravity of cast iron is about 7.2, the weight per cubic inch being 0.26 pound. Cast iron melts at about 2300 degrees F. Its linear expansion per unit length, due to heat, per degree F. is 0.00000556. The physical properties of castings are influenced by the casting temperature, rate of cooling, etc., so that the probable strength and stiffness of a casting can be estimated only in a general way.

Cast Iron, Alloy Type. Alloy cast irons are used for various applications requiring strength and resistance to wear. Numerous compositions provide varying properties suitable for different classes of service. There are eight S.A.E. compositions used for such parts as cylinders, cylinder liners, brake-drums, sprockets, clutch plates, and pistons. These eight compositions contain from 2.80 to 3.40 total carbon; from 0.40 to 0.83 combined carbon; from 0.50 to 0.75 manganese; from 2 to 2.35 silicon. In addition, one or more of the alloying elements chromium, copper, molybdenum and nickel are used, but the kinds and amounts of these alloying elements are not specified because of specific service requirements, variations in foundry practice, possible variations in combinations of the alloying constituents. The tensile strength of alloy cast irons range for some applications from

35,000 to 45,000 pounds per square inch, and from 55,000 to 65,000 for classes of service requiring greater strength.

Nickel-Chromium Cast Iron: A corrosion- and heat-resistant cast iron having the same coefficient of expansion as plain cast iron at elevated temperatures consists of 28 to 32 per cent nickel, 4 to 5 per cent chromium, and the remainder cast iron. It is very tough, is machinable, and maintains its properties without deterioration at high temperatures. The hardness is from 140 to 240 Brinell, and the tensile strength is approximately 30,000 pounds per square inch. This metal is intended for use in contact with plain cast iron or steel—for example, as a liner or insert—where it will attain a higher temperature than its surroundings, and must pass through the heating and cooling cycles without becoming separated from the base metal that surrounds it. Examples of its application are bushings and liners for pumps and compressors that handle hot liquids or vapors and automobile-engine valve-seat inserts.

Cast-Iron Growth. The "growth" of cast iron is a peculiarity of certain kinds of cast iron to increase in size after repeated heatings. Cast-iron annealing ovens, 8 feet in length, which are kept red hot for prolonged periods between which they are permitted to cool off, sometimes grow to 9 feet in length in the course of their use. Cast-iron furnace grates, range fittings, etc., subjected to alternate heating and cooling are also frequently distorted and sometimes broken from the same cause. To avoid "growth" as much as possible, white cast iron should be used, which has a carbon content of about 3 per cent, and which is as free from silicon and other impurities as possible.

In a series of experiments by A. E. Outerbridge, Jr., for determining the growth of cast iron and its causes, a cast-iron bar of 1 by 1-inch section, 14 13/16 inches in length, was heated 27 times to about 1470 degrees F. for one hour. During this treatment it increased in size to 16½ inches length and 1⅛ by 1⅛-inch cross-section. This corresponds to an expansion of nearly 41 per cent. The enlarged bar had the same weight as the bar before the treatment. Twelve additional heatings increased the dimensions of the bar until the total expansion was 46 per cent.

Cast Iron, Nichrome In. See under Nichrome.

Cast-Iron Pipe. See Pipe.

Castolin. Permits welding at low temperatures, so that overheating and subsequent warping of welded parts are avoided and stresses are eliminated. Lengthy preheating is also made unnecessary. The tensile strength ranges from 35,000 to 115,000 pounds per square inch. Furnished in rod form in a variety

of alloys for the welding of aluminum, steel, cast iron, brass, bronze, copper, and white metal. Castolin fluxes are also available in paste or powder form.

Cast Steel. The term "cast steel" is sometimes used to designate what is known as tool steel or crucible steel, but this usage is becoming more and more obsolete and should be discontinued, as it is confusing. Steel castings made by pouring molten steel into suitable molds are sometimes referred to as cast steel, but the latter term should not be applied to the high-carbon steel which is made by the crucible or electric processes and is suitable for cutting tools.

Cast Welding. A process for welding together parts, usually of metals with a comparatively low melting point, by preparing a mold around the parts to be joined and pouring molten metal between them.

Catalytic Agent. A substance present in a chemical reaction which does not take a direct part in the reaction, but which remains the same throughout, or is only temporarily affected; this agent may accelerate or retard the rate at which the reaction takes place.

Catenary Curve. The *catenary* is the curve assumed by a string or chain of uniform weight hanging freely between two supports. The cables of a suspension bridge, if uniformly loaded, assume the form of the catenary curve. It has, therefore, considerable importance in structural engineering.

Cathode. The electrodes by means of which current enters and leaves any conductor of the non-metallic class, such as an electrolyte, are known as *anode* and *cathode,* respectively. A cathode is an electrode through which current leaves any conductor of the non-metallic class. Specifically an electrolytic cathode is an electrode at which positive ions are electrically discharged, or negative ions are formed, or at which other reducing reactions occur. See also Anode.

The heated, incandescent filament in a vacuum tube which emits a stream of electrons is designated as a *cathode.* Where the electrons emitted are formed into a directed "beam" as in an oscillograph or television type of vacuum tube, such an electronic "beam" is called a *cathode ray.*

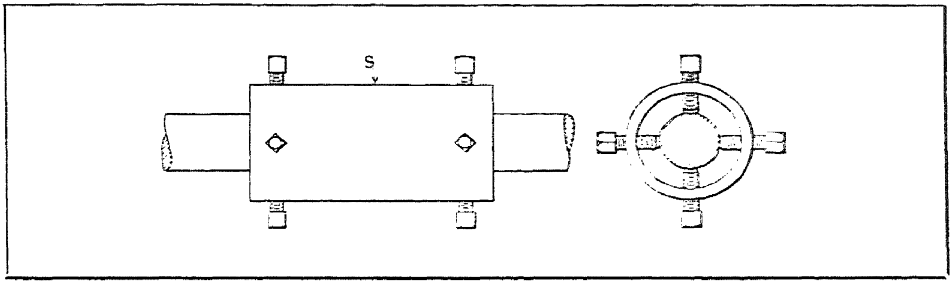
Cat-Head. A device used in a lathe when it is required to apply a steadyrest to a surface that does not run true and which is not to be turned. This is simply a sleeve *S* (see illustration) which is placed over the untrue surface to serve as a bearing for the steadyrest. The sleeve is made to run true by adjusting

the four set-screws at each end, and the jaws of the steadyrest are set against it, thus supporting the work.

Catty. A modern Chinese measure of weight legalized in 1908, equal to 596.8 grams or 21.05 ounces avoirdupois.

Cecolloy. A nickel-molybdenum, air-furnace iron alloy having a fine homogeneous grain structure and a tensile strength of from 40,000 to 60,000 pounds per square inch. Suitable for making large castings weighing up to 50 tons. Used for forming dies, beds of heavy-duty machines, steam cylinder liners and rings, crushing machinery, etc.

Cellucraft. A plastic coating for metal, wood, and rubber, applied by spray guns; available in bright colors, pastel shades, "metal tones," and other effects, obtained by pigmenting the



Cat-head which is sometimes used as a Steadyrest Bearing

coating material. A similar material known as "Macoid" is applied by dipping. Applicable to the finishing of automobile hardware, such as window regulators, door handles, and control knobs; die-castings in general; and molded rubber steering wheels.

Celluloid. Celluloid is a dried solution of gun-cotton (pyrrolin) and oil. It may be machined or molded into any form by softening it in boiling water. It is highly combustible and gives off extremely poisonous fumes when burning. It is only slightly affected by moisture but is soluble in alcohol. Celluloid is a good electrical insulating material, although its insulation qualities are greatly reduced at high temperatures. It can be easily molded at 100 degrees C., is highly elastic, and has considerable tensile strength.

Celluloid Bonding Process. Grinding wheels made by the celluloid process have a bond of celluloid, as the name implies. The abrasive grains are mixed with celluloid and this mixture is

rolled into sheets from which the wheels are cut. After seasoning for several months, the wheels are ready to finish.

Celsius Thermometer. See Centigrade Thermometer.

Cement. The cements generally used in engineering construction are of three kinds, Portland, natural, and Pozzuolanic (slag) cements. The most reliable of these is the Portland cement, and this kind should always be used in reinforced concrete construction. This cement consists of chemical compounds of lime and silica and lime and alumina which, when combined with water, form crystalline substances of great mechanical strength, which are capable of adhering firmly to such materials as stone and sand. See Portland Cement.

Cementation Process. The *cementation process* is an obsolete method for producing tool steel from wrought-iron bars. The iron bars were packed in air-tight retorts with powdered charcoal between the bars. The retorts were then put into a furnace called the "cementation" furnace, where they were heated to a red heat and permitted to remain at that temperature for several days. During this time the iron absorbed carbon from the charcoal up to about 1½ per cent of its own weight. The carburized bars, called *blister steel,* were then cut up into small pieces and were remelted in crucibles from which the metal was poured into molds. The billets thus formed were afterwards hammered or rolled into the required shapes. The carburizing of steel in the ordinary casehardening process is often referred to by many writers as "cementation."

Cementite. Cementite is a carbide of iron having the chemical formula Fe_3C. Steel which has cooled slowly from a high temperature contains ferrite, cementite and pearlite, in relative proportions which vary according to the chemical composition of the steel.

The strength of ordinary cast iron depends largely upon the proportion of cementite (combined carbon) and graphitic carbon. See Steels.

Cement, Leather. Leather cement is a composition suitable for attaching leather, or leather to metal. A very good cement for leather on leather is made from equal parts of good hide glue and isinglass, softened in water for ten hours and then boiled with pure tannin until the whole mass is sticky. The surface of the leather to be cemented is roughened and the cement applied hot.

Cement, Mica and Steel. A gum and plaster-of-paris cement that has good adhesive qualities for attaching mica to steel is made by dissolving 1½ ounces of gum acacia in a half pint of

boiling water and adding sufficient plaster-of-paris to form a paste. The materials to which the cement is applied should be pressed together as tightly as possible, in order to squeeze out the air bubbles.

Litharge, lead, and varnish form a good adhesive by mixing two parts of litharge and one part of white lead, and working them into a pasty condition by using three parts of boiled linseed oil and one part of copal varnish. See also Glue for Mica and Steel.

Cements for Joints. A strong cement which is oilproof, waterproof, and acid-proof, consists of a stiff paste of glycerin and litharge. These form a chemical combination which sets in a few minutes. If a little water is added, it sets more slowly, which is often an advantage. This cement is mixed when required for use.

Mixture for Threaded Pipe Joints: A good material to apply to pipe threads before making up the joints, in order to obtain a tight joint that will resist the action of gases or liquids, is made of red lead mixed with pure boiled linseed oil. This mixture has been widely used and is very satisfactory. It should have a heavy fluid-like consistency, and if applied to a clean, well-cut thread will give an excellent joint.

Shellac for Pipe Connections: Shellac has proved to be a very satisfactory substitute for lead in sealing air and gas pipe connections. It is applied with a brush to the joints and hardens very rapidly, and being brittle, the pipes can be readily disconnected.

Graphite, Litharge, Chalk Cement: A good cement for use in making steam pipe joints is made in the following manner: Grind and wash in clean cold water 15 parts of chalk and 50 parts of graphite; mix the two together thoroughly and allow to dry. When dry regrind to a fine powder, to which add 20 parts of ground litharge and mix to a stiff paste with 15 parts of boiled linseed oil. The preparation may be set aside for future use, as it will remain plastic for a long time, if placed in a cool place. It is applied to the joint packing as any ordinary cement.

Sulphur, Graphite, Lime Cement: To make cement for steam, air and gas pipes, mix thoroughly powdered graphite, 6 parts; slaked lime, 3 parts; sulphur, 8 parts, and boiled oil, 7 parts. The materials must be thoroughly mixed by protracted kneading until perfectly smooth and free from lumps.

White and Red Lead Mixture: Mix in ordinary white lead, enough powdered red lead to make a paste the consistency of putty. Spread this mixture on the joint, and when it hardens, the joint will be water tight. This mixture was used on standpipe flanges after testing all kinds of rubber gaskets without

success. The mixture hardened and make a tight joint, never leaking afterward.

Steam-tight Joints: Use white lead ground in oil and add to it as much black oxide of manganese as possible and a small portion of litharge. Knead with the hand, dusting the board with red lead. The mass is made into a small roll and screwed or pressed into position, the joint being first slightly oiled with linseed oil.

Cement for Steam and Water Pipes: A good cement for joints on steam or water pipes is made as follows: 10 pounds fine yellow ochre; 4 pounds ground litharge; 4 pounds paris white (whiting), and ½ pound of hemp cut up fine. Mix together thoroughly with linseed oil, to about the consistency of putty.

Mixture for Rust Joint: Mix 10 parts of iron filings, 3 parts chloride of lime with enough water to make a paste. Apply this mixture to the joint, bolt firmly together and in twelve hours it will set.

Permanent Cement for Steam Pipes: To make a permanent cement used for stopping leaks in steam pipes where calking or plugging is impossible, mix black oxide of manganese and raw linseed oil, using enough oil with the manganese to bring it to a thick paste; apply to the pipe or joint at leak. It is best to remove pressure from the pipe and keep it sufficiently warm to absorb the oil from the manganese. In twenty-four hours the cement will be very hard.

High-pressure Water Pipes: A highly recommended packing and cement, combined, for making tight joints in high-pressure water pipes, is made as follows: Mix with boiled linseed oil, to the consistency of putty, these ingredients: Ground litharge, 10 pounds; plaster-of-paris, 4 pounds; yellow ochre, ½ pound; red lead, 2 pounds; cut hemp fiber, ½ ounce. The hemp fiber should be cut in lengths of about ½ inch, and thoroughly mixed into the putty material. Its office is to give consistency to the cement. The cement is applied to the joint similarly to any other cement. It dries thoroughly in from 10 to 12 hours.

Cement to Resist Acids: A cement that withstands hydrochloric acid vapors consists of resin, 1 part; sulphur, 1 part; fireclay, 2 parts. A cement compound of boiled linseed oil and fireclay acts well with most acid vapors. A composition of glycerin and litharge is useful in this connection, especially when made up according to the following formula: Litharge, 80 pounds; red lead, 8 pounds; "flock" asbestos, 10 pounds. It should be fed into a mixer, a little at a time, with small quantities of boiled oil (about six quarts of oil being used). Sockets in 3-inch pipes carrying nitric acid, calked with this preparation, showed no leaks in nine months.

Packing to Resist Gasoline Vapor: To prepare packing for joints in pipes, etc., carrying gasoline vapor, mix a quantity of graphite and kerosene to a thick paste and apply the paste to both sides of sheet asbestos. When dry, the packing may be cut to the shape desired. The graphite helps the asbestos to make intimate contact with the iron and thus maintain a tight joint continuously at high temperature for an indefinite time.

Center Indicator. The center test indicator is used for setting a center-punch mark (the position of which corresponds with the center or axis of the hole to be bored) in alignment with the axis of a lathe spindle.

Centering Machines. Many shops have a special machine for forming centers in the ends of parts preparatory to turning the parts in a lathe. One type of centering machine is equipped with two centering heads so that both ends may be centered without reversing the position of the work.

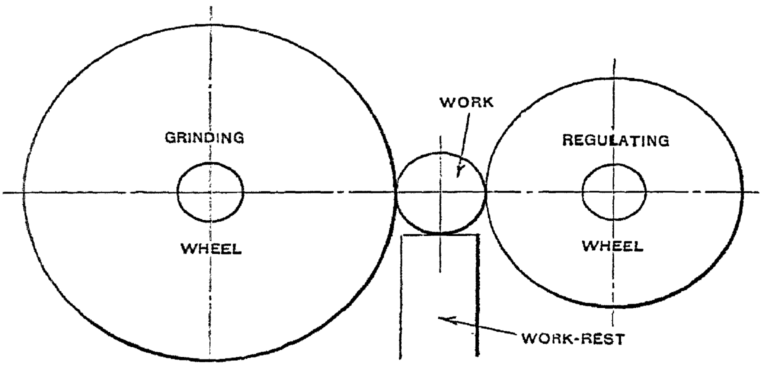
Centering Mechanisms. Centering mechanisms, in machine design, are devices used for automatically returning a machine member to the starting point or central position.

Centerless Grinding. Centerless grinding is the grinding of cylindrical work without supporting it on centers in the usual way. The principle of centerless grinding is illustrated by the diagram. Two abrasive wheels are mounted so that their peripheries face each other, one of the wheels having its axis so arranged that it can be swung out of parallel with the axis of the other wheel by varying amounts, as required. Between these two abrasive wheels is a work-supporting member equipped with suitable guides. The grinding wheel forces the work downward against the work-rest and also against the regulating wheel. The latter imparts a uniform rotation to the work which has the same peripheral speed as the regulating wheel, the speed of which is adjustable.

Through-feed Grinding: There are three general methods of centerless grinding which may be described as through-feed, infeed, and end-feed methods. The through-feed method is applied to straight cylindrical parts. The work is given an axial movement by the regulating wheel and passes between the grinding and regulating wheels from one side to the other. The rate of feed depends upon the diameter and speed of the regulating wheel and its inclination which is adjustable. It may be necessary to pass the work between the wheels more than once, the number of passes depending upon such factors as the amount of stock to be removed, the roundness and straightness of the unground work, and the limits of accuracy required.

In-feed Grinding: When parts have shoulders, heads or some part larger than the ground diameter, the in-feed method usually is employed. This method is similar to the "plunge cut" form grinding on a center type of grinder. The length of the section or sections to be ground in any one operation is limited by the width of the wheel. As there is no axial feeding movement, the regulating wheel is set with its axis approximately parallel to that of the grinding wheel, there being a slight inclination to keep the work tight against the end stop.

End-feed Grinding: The end-feed method is applied only to taper work. The grinding wheel, regulating wheel, and the blade or work-rest are set in a fixed relation to each other and the work is fed in from the front mechanically or manually to a fixed end



Principle of the Centerless Grinding Process

stop. Either the grinding or regulating wheel, or both are dressed to the proper taper.

Automatic Centerless Grinding: The grinding of relatively small parts may be done automatically by equipping the machine with a magazine, gravity chute, or hopper feed, provided the shape of the part will permit using these feeding mechanisms.

Rates of Production: Rates of production vary widely according to the character of the work, the material, the accuracy and finish required, and other factors. For example, production often varies from two or three hundred up to several thousand pieces per hour. As a general rule, parts ground by the through-feed method require two passes and from 0.010 to 0.015 inch of stock is removed; however, when an extra-fine finish and extreme accuracy are essential, as for piston-pins, etc., the number of passes is increased. Most work is ground either by the through-

feed or in-feed methods. The rate of production with the through-feed method depends chiefly upon the amount of stock to be removed, whereas, with the in-feed method, the production rate is limited to a considerable extent by the time required for loading and unloading.

Centerless Grinding, Internal: Internal grinding machines based upon the centerless principle utilize the outside diameter of the work as a guide for grinding the bore which is concentric with the outer surface. In addition to straight and tapered bores, interrupted and "blind" holes can be ground by the centerless method. When two or more grinding operations must be performed on the same part, such as roughing and finishing, the work can be rechucked in the same location as often as required.

Center of Buoyancy. The center of gravity of the liquid displaced by a body immersed in it. See Buoyancy.

Center of Gravity. Under the influence of gravity, all bodies tend to move toward the earth's center. Gravity acts at every point of a body. All bodies are composed of particles, each of which has weight, and, consequently, each is attracted by gravity. A body, therefore, is really drawn downward by a large number of forces of gravity—as many as there are molecules in the body. Gravity acts in the direction of lines converging or meeting at the center of the earth, a point so far distant, compared with the dimensions of any bodies that are likely to be considered, that these lines of action are always assumed to be parallel. It is always assumed, however, that gravity acts as a *single force* at a point called the *center of gravity.* Into whatever position a body may be placed, there is always one invariable point through which the resultant of the attracting forces always passes. This point is the center of gravity. It is a point at which, if a single force of gravity were to act in place of all the other forces, and equal in intensity to their sum, the effect upon the body would be the same as before.

Center of Oscillation. If a body oscillates about a horizontal axis which does not pass through its center of gravity, there will be a point on the line drawn from the center of gravity perpendicular to the axis, the motion of which will be the same as if the whole mass were concentrated at that point. This point is called the *center of oscillation.* The distance between the center of oscillation and the point of suspension is called the *radius of oscillation.*

Center of Percussion. If a body oscillates about an axis, then the point at which, if a blow is struck by the body, the percussive action is the same as if the whole mass of the body were

concentrated at that point, is called the *center of percussion.* This point is located at the same point as the center of oscillation.

Center Reamers. A "center reamer" is a reamer the teeth of which meet in a point. By their use small conical holes may be reamed in the ends of parts to be machined as on lathe centers. When large holes—usually cored—must be center-reamed, a large reamer is ordinarily used in which the teeth do not meet in a point, the reamer forming the frustum of a cone. Center reamers for such work are called "bull" or "pipe" center reamers.

Center, Machine Tool. The centers of a machine tool, such as a lathe or grinding machine, are the conical points between which the part to be turned or ground is held. The work revolves upon the stationary or *dead center* of the tailstock and revolves with the *live center* in the headstock spindle. Experiments have shown that on lathe work at both high and low speeds the life of high-speed steel centers is easily ten times that of carbon-steel centers. In cases where the work is long and of fairly small diameter, when carbon centers are likely to burn off due to the expansion of the work being machined, the danger of spoiled centers and spoiled work seems to be entirely overcome by the use of high-speed steel centers. In grinding machines, high-speed steel centers also seem to stand the wear of the abrasive which gets into the cutting compound and which deteriorates the carbon-steel centers very rapidly. By using a chrome-nickel steel shank and a high-speed steel point a satisfactory center can be made at a much lower cost than one made entirely of high-speed steel.

Angle of Lathe Centers: In the United States the standard included angle for the work-supporting ends of lathe centers is 60 degrees. This angle is increased to 75 degrees for some axle turning or other heavy-duty lathes. British standard lathe centers have an angle of either 60 or 75 degrees as specified by the purchaser. For lathes engaged in turning axles for railway rolling stock, the angle of 75 degrees has been adopted by the British Railway Companies.

Centigrade Thermometer. This thermometer, also known as the Celsius, was originated by the Swedish astronomer Celsius, who, in 1742, described a thermometer provided with 100 graduations between the freezing and boiling point of water. On the Centigrade thermometer scale, the zero point is placed at the freezing point of water, and the graduation "100" coincides with the boiling point of water; hence, the zero on the Centrigrade scale corresponds to the 32-degree graduation on the ordinary Fahrenheit thermometer, and the 100-degree graduation on the

Centigrade scale corresponds to the 212-degree graduation on the Fahrenheit scale.

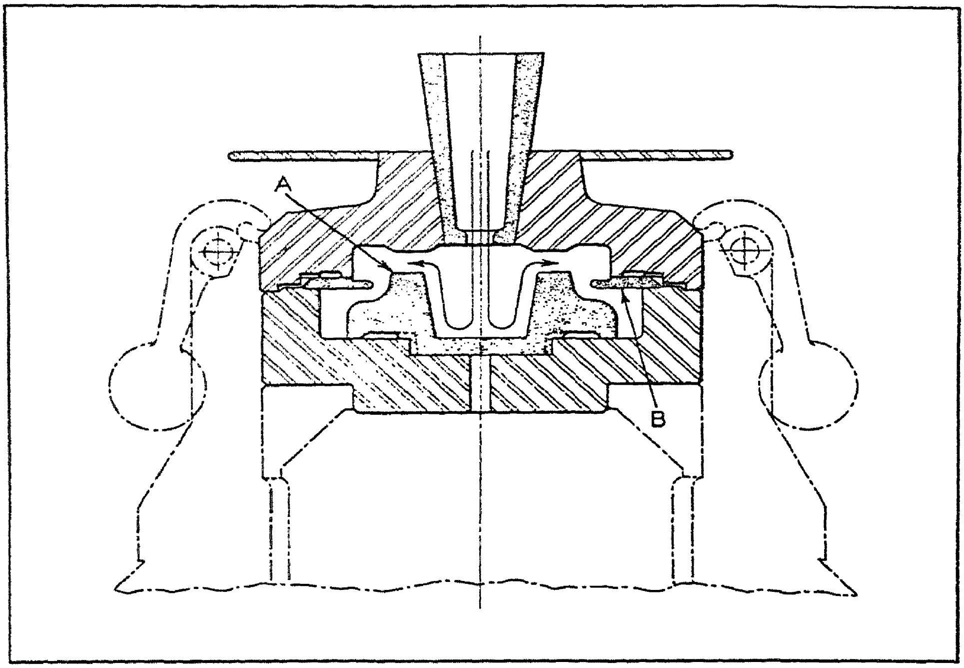
$$\text{Degrees Fahrenheit} = \frac{9 \times \text{degrees C.}}{5} + 32$$

Centimeter-Gram-Second Measurement System. See Absolute System of Measurement.

Centrifugal Blower. A blower operating on the same principle as the ordinary ventilating fan, but designed for maintaining pressures from 3 to 4 pounds per square inch and used for cupola furnaces and similar requirements.

Centrifugal Casting. The centrifugal casting of metals is an old art, but it did not assume commercial importance until recent years. This process has already become an important factor in such work as the manufacture of paper-mill rolls, railroad car wheels, and cast-iron pipe. The centrifugal casting process has been successfully applied in the production of non-metallic tubes, such as concrete pipe, in the production of solid castings by locating the molds around the rim of a spinning wheel, and also to a limited extent in the production of solid ingots by a largely similar process. The usual way of casting hollow objects such as cast-iron pipe, is by introducing molten metal into a spinning mold. Where the chilling of the metal is extremely rapid, as, for example, in casting cast-iron pipe against a water-cooled chilled mold, it is imperative to use a movable spout, the latter sliding at a certain predetermined rate so that by the time the nozzle discharging the metal comes out of the mold the entire pipe is completed. The particular feature that determines the field of application of hot-mold centrifugal casting is the ability to produce long cast shapes of comparatively thin metal.

Centrifugal Casting of Gear Blanks. The accompanying diagrams illustrate how centrifugal casting is applied at the Ford plant in producing steel castings for different types and sizes of transmission gears. The molten metal is transferred by ladles suspended from monorails to the pouring stations of four large turntables equipped with steel dies or molds. Eighteen molds are mounted around each turntable. The rims of the blanks on which gear teeth are later to be cut, are cast directly against the steel walls of the molds, which gives a refining effect. Each mold is made with a cope and a drag. As each mold approaches the pouring station, with the continued rotation of the turntable, a motor drive beneath the mold is automatically started to revolve it during pouring and cooling. The speed of rotation varies somewhat with the diameter of the gear, a speed of 350 R.P.M. being employed in the case of 7½-inch diameter tractor gears.

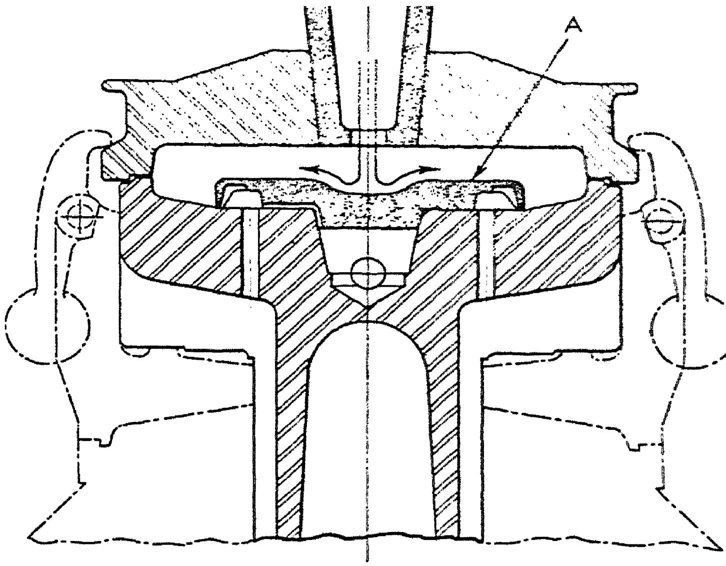


Typical Mold Used in Centrifugal Casting of Gears, which Shows Arrangement of Cores for Recesses in the Gear Blanks

While the molds pass through the pouring and cooling stations, they are guarded on the sides and on top by sheet-metal covers. The pouring temperature of the molten metal is between 3850 and 2900 degrees F.

After spinning around for two minutes, the molds reach the unloading station. Here the rotation of the mold is automatically stopped to enable the casting to be removed and new cores to be inserted. At the same time, a cam mechanism beneath the turntable causes three vertical rods to rise beneath the bottom plate of the mold, so that the casting and cores are lifted with respect to the outer mold walls, and the casting is thus stripped from the mold. The cam holds the mold in the raised position until new cores have been inserted; the mold then drops back to the pouring position just before the mold drive is engaged.

The construction of two typical molds is shown by the diagrams. From the position of cores *A* and *B*, it will be seen that recesses and contours can readily be obtained on the sides or backs of gears for lightness or engineering design that would necessarily have to be machined on practically solid forged blanks. This feature of the centrifugal casting process provides substantial economies from the standpoint of scrap material and machining costs. Proper venting of the molds, which



Cross-sectional Drawing of a Mold Used in Centrifugally Casting Differential Ring Gears for Tractors

is done underneath, is of utmost importance in obtaining castings that are free of imperfections. Each revolution of the turntable and, therefore, the casting of eighteen gears takes place in four minutes. This means a possible production of 270 gears an hour from each of the four turntables. The use of steel molds enables dimensional limits on the gear blanks to be maintained easily. From 1/32 to 1/16 inch of stock is generally allowed for the machining of these blanks. The dies and molds used in the centrifugal casting process are made from three different steels. Steels with a low percentage of carbon and with both chromium and molybdenum, or with either chromium or molybdenum, have been found satisfactory.

From the casting turntables, the gear blanks are placed on conveyors which carry them directly to an annealing furnace. After annealing, the blanks are shot-blasted, and then sent to the machining department.

Compositions of Cast Gears: Truck ring gears, which are later carburized, are made from a steel of the following analysis: Carbon, 0.18 to 0.25 per cent; copper, 0.50 to 1.50 per cent; silicon, 0.20 to 0.40 per cent; manganese, 0.40 to 0.60 per cent; molybdenum, 0.25 to 0.35 per cent; chromium, 0.10 per cent maximum; phosphorus, 0.05 per cent maximum; sulphur, 0.05

per cent maximum; and nickel, from 1.65 to 2 per cent. After carburization, these truck gears are direct-quenched or reheated and oil-quenched, and then drawn to a hardness of between 58 and 62 Rockwell C.

Transmission countershaft gears and differential ring gears for passenger cars are cast from a steel of the following analysis: Carbon, 0.30 to 0.38 per cent; copper, 0.50 to 1.50 per cent; silicon, 0.20 to 0.40 per cent; manganese, 0.55 to 0.75 per cent; molybdenum, 0.10 to 0.20 per cent; chromium, 0.80 to 1 per cent; phosphorus, 0.05 per cent maximum; and sulphur, 0.05 per cent maximum. These gears are normalized to from 170 to 196 Brinell, and, after machining, are hardened and tempered to about 477 Brinell.

Transmission gears for tractors and trucks are cast from an analysis similar to that just given, except that the carbon content is between 0.38 and 0.45 per cent. These gears are normalized to the same Brinell reading as the passenger car gears, and, after machining, are hardened to a similar degree.

Physical Properties: The physical properties of the passenger-car gears mentioned and the tractor and truck transmission gears, after being hardened by heating to 1500 degrees F. and quenched in oil, and then tempered by reheating to 355 degrees F., are as follows: Elastic limit, 212,000 pounds per square inch; tensile strength, 218,000 pounds per square inch; elongation in 2 inches, 0.75 per cent; reduction in area, 3 per cent; and Brinell hardness, 477.

Centrifugal Compressor. A blower used for pressures from 6 to 120 pounds per square inch or more; same as *turbo compressor.*

Centrifugal Dryers. See Dryers, Centrifugal.

Centrifugal Feed-Pumps. The centrifugal boiler feed-pump has many characteristics which are superior to the well-known plunger pump although the plunger pump may be preferable, providing it is large enough to run at slow speed. A plunger pump should preferably not be operated faster than 30 strokes a minute, nor with a piston speed of over 60 feet a minute. Some of the advantages of the centrifugal boiler feed-pump are as follows: Steady pressure on entire feed system; no regulators necessary, because pressure seldom increases over 15 or 20 per cent at no output; lower maintenance cost; less floor space; and lower steam consumption. One disadvantage is the possibility of excessive heating of the pump casing when operated at full speed and practically no output. Some operators prefer pump governors, but because of the long periods of inactivity the ordinary pump governor frequently does not work when required.

The high suction head needed when pumping warm water and the possibility of reduced output, due to erosion of the wearing rings, are other disadvantages.

Centrifugal Force. If a body, as, for example, a weight fastened to a string, is revolved in a curved path, a pull is exerted on the string, which increases with the velocity with which the body is revolved. According to the laws of motion, a body tends to move in a straight line unless it is acted upon by some external force which causes it to change its direction; hence, a body revolving as mentioned would tend to move in a line tangential to the circle in which it revolves, if it were not restrained from doing so by the string. The force exerted by the body upon the string or cord which restrains it is called the *centrifugal force.* Whenever any body revolves about a center it exerts a centrifugal force upon the arm or cord which restrains it from moving in a straight (tangential) line. The centrifugal force increases rapidly with the velocity, the increase being in proportion to the square of the velocity, so that, if the velocity is doubled, the centrifugal force becomes four times as great; if the velocity is made three times as great, the centrifugal force becomes nine times as great, etc. The centrifugal force also increases directly with the weight of the revolving body, but decreases with an increasing radius.

Centrifugal Pumps. A centrifugal pump in its simplest form consists of an outer casing in which inlet and outlet passages are formed and which encloses a revolving impeller, rotor, fan, bucket or runner, various names being applied to this part. The impeller has blades which are usually curved backward with reference to the direction of rotation. When the pump is in operation, the water is drawn in through the center or "eye" of the impeller, and as the water is whirled around by the blades, it is thrown outward as the result of centrifugal force and passes through the discharge outlet. The early designs of centrifugal pumps were only adapted to low pressures, and were used for forcing large quantities of water to small heights, in connection with the drainage and irrigation of land, emptying locks, and similar classes of work for which a reciprocating piston pump of sufficient capacity would have been too large and expensive. The modern centrifugal pump has been developed until the various types and designs now available are adapted to various classes of service and for high heads or pressures.

Advantages of Centrifugal Type: The principal advantages of centrifugal pumps, as compared with the reciprocating type, are greater compactness, lower initial cost, adaptability to a greater variety of conditions, little attention while operating, simplicity

of construction, and reliability. The centrifugal pump has another decided advantage in that it can be directly connected to a steam or gas engine, steam turbine, or electric motor. These pumps deliver water continuously, so that shocks in the pipe lines are avoided, and they operate with little or no vibration, which makes it unnecessary to install a heavy foundation. If the impeller blades are carefully designed, it is possible to close a valve at the end of the discharge line without an increase in pressure, so that the pump is capable of operating under practically all conditions, without danger of breakage.

Classes of Centrifugal Pumps: There are two principal classes of centrifugal pumps, namely, the *single-stage* pump and the *multi-stage pump.* The single-stage type of pump has a single impeller. The head of water which single-stage pumps of commercial design are capable of developing does not vary widely from the result obtained by the formula:

$$= \frac{1}{2g},$$

in which V = peripheral velocity of the impeller in feet per second; and g = acceleration of gravity, or 32.16 feet per second.

By arranging a number of centrifugal pumps in series so that the discharge of one is led to the suction of the succeeding pump, the head developed may be multiplied to any desired extent. Some of the early designs of multi-stage pumps were practically a series of single-stage pumps arranged in series, with but little modification of the construction. The modern designs, instead of having individual housings or casings for each pump, are equipped with one common housing with passages so arranged that the water flows from the discharge of one pump to the inlet of the next pump, through channels or passageways designed to reduce the losses through friction and eddy-currents as much as possible.

Ceralumin. An alloy of low specific gravity and comparatively high strength. Chilled castings, heat-treated, have a tensile strength of from 46,000 to 54,000 pounds per square inch; sand castings, heat-treated, from 38,000 to 40,000 pounds per square inch. Brinell hardness, 130 to 140. For use wherever light-weight, high-strength castings with high fatigue value are of importance.

Cerium. Cerium is one of the metallic chemical elements; its chemical symbol is Ce, and its atomic weight, 140.25. The metal has some similarity to iron in its appearance. The industrial importance of cerium is due to the use of its dioxide in the making of incandescent gas mantels. This dioxide is a white

or pale yellow compound which, when heated to a high temperature, will give out a white brilliant light.

Cetec No. 1389. A cold-molded plastic compound with good heat resistance and fine appearance. Unaffected by temperatures up to 480 degrees F. Has high dielectric strength. Transverse strength, 6000 pounds per square inch. Intended for insulating applications—suitable for heat-control knobs of electric irons, cord-connector plugs, etc.

Chain. A surveyor's length measure; 1 chain = 4 rods = 22 yards = 66 feet = 100 links = 20.117 meters.

Chain Annealing. The annealing of chains before they are first used is good practice, as in that way any internal stresses that may have been set up in the process of manufacture are thereby relieved. Annealing a fatigued or crystallized chain may improve its ductility without restoring its original physical properties. In every case, however, the annealing should be carefully performed under proper conditions as to determination and control of the temperature, and with a full knowledge of the chemical composition of the material under treatment.

Chain, Engineer's. See Engineer's Chain.

Chain-Hardening Furnace. A special furnace in which the chain to be heat-treated passes over two sprockets, one at the entering and one at the leaving end of the furnace. After the chain has passed through the heating chamber, it enters directly into a cooling bath (without passing through the outer air) and then passes over the leaving sprocket and is wound upon a reel.

Chain-Making Machine. A machine employed for the making of chain of either the weldless or welded type. Some of these machines are merely wire- or rod-bending machines that bend the links to the required size, while others, generally of the electric type, include an arrangement for welding.

Chain Materials. The best material for crane and hoisting chains is a good grade of wrought iron, in which the percentage of phosphorus, sulphur, silicon, and other impurities is comparatively low. The tensile strength of the best grades of wrought iron does not exced 46,000 pounds per square inch, whereas mild steel with about 0.15 per cent carbon has a tensile strength nearly double this amount. The ductility and toughness of wrought iron, however, is greater than that of ordinary commercial steel, and for this reason it is preferable for chains subjected to heavy intermittent strains, because wrought iron will always give warning by bending or stretching, before breaking. Another important reason for using wrought iron in pref-

erence to steel is that a perfect weld can be effected more easily.

Heavy welded chains of either mild steel or wrought iron have been supplanted in many cases by cast-steel chain. Mild-steel chain has been found to be either too ductile to retain its form under severe stress or too hard to insure reliable welds when the links have been welded together. Cast-steel chains are made successfully and practically either by casting the whole chain integral or by pouring the metal into separate link molds and then setting these links in alternate molds and pouring the intervening links around those first cast. Chains of almost any size can be, and have been, successfully cast, either integral or by alternate molds. The steel used is a special alloy electric steel; it is stated that electric steel is the only grade of steel that can be used successfully and even this steel must be specially heat-treated. The steel casting chains are very strong and of excellent durability. It is essential that steel casting chains be carefully annealed.

Chain Nomenclature, Roller. See Roller Chain Nomenclature.

Chain Oiling. A method used for lubricating horizontal journals running at high speed, in which an endless loop of chain, resting on and moving with the shaft, dips into an oil reservoir at the lower side and brings up the oil to the top surface of the journal, from where it flows over into the oil grooves.

Chain Slings. See Slings.

Chain Speeds, Roller. See Roller Chain Speeds.

Chain Sprocket Design. See Sprocket.

Chain Strength. The ultimate, or breaking, strength of a chain is usually between 1.5 and 1.7 (average 1.66) times the ultimate strength of the straight bar or stock from which it is formed, instead of twice that amount, as might at first thought be expected because of the doubling of the bar in forming the link. The link of a chain under load is not in the simple physical condition of a bar under direct tension in a testing machine. A link is subjected to a direct tension, due to the load or pull, and to a bending moment that induces tension on the outer fibers and compression on the inner fibers of that part of the link subject to bending. The stress in tension due to bending may equal more than three (for stud links) or four (for open links) times that produced by the direct pull evenly distributed over the cross-sectional area of the bars.

Another empirical formula that is commonly used for calculating the breaking load, in pounds, of wrought-iron crane chains is: $W = 54{,}000\ D^2$, in which W = breaking load in pounds and D = diameter of bar (in inches) from which links are made. The

working load for chains should not exceed one-third the value of *W*, and, in many cases, it should be less. When a chain is to be wound around parts such as castings, and severe bending stresses are to be introduced, a greater factor of safety should be used.

Safe Working Loads: An investigation of these matters conducted at the Engineering Experiment Station of the University of Illinois, with a critical analysis of the results attained, affords a simple and convenient formula for ascertaining the actual maximum stresses in chains and links under specified loads due to combined pull and bending, and thus furnishes a reliable means of computing safe working loads for chains. This formula, for chains with open links of the usual form, is as follows:

$$F = 2.5 \times \frac{P}{D^2}.$$

For chains with stud links,

$$\mathrm{F} = 2 \times \frac{P}{D^2}.$$

In these formulas, F = extreme fiber stress in tension, in pounds per square inch; D = diameter of stock, in inches; P = chain load, in pounds.

In computing the safe loads for open-link chains a value of 12,000 pounds per square inch for the allowable maximum fiber stress, and an elastic limit of 24,000 pounds per square inch may be used, thus assuring in every case an actual safety factor of at least 2, based on the elastic limit of wrought iron, or more if open-hearth, low-carbon steel is used.

Chains, Studded. Tests have demonstated that the ultimate breaking strength of a chain with studded links is less than that of an unstudded chain. This is probably due to the fact that the open links of an unstudded chain collapse until the sides are approximately parallel, so that the stresses are lower than in the studded links, the sides of which are prevented from collapsing by the studs. The principal function of the stud is to prevent the chain from kinking and catching, so that it will run free from chain lockers, etc. The stud also prevents the chain from becoming rigid under heavy strains.

Chain Transmission. This term relates to the use of chains and sprockets for transmitting power. This system of power transmission provides a positive speed ratio between the driving and driven shafts, and it is especially adapted where the center distances between the shafts are too long for gearing and too short for belting. Chain drives are compact, and as there is no initial tension on the chain, journal friction is minimized. See Silent Chain Transmission; Roller Chain; Sprocket.

Chang. A Chinese length measure, legalized in 1908. It is equal to 3.2 meters, or 10 feet 6 inches.

Change-Gears. The gears used on screw-cutting lathes for connecting the lathe spindle stud and the lead-screw are commonly known as *change-gears.* Prior to the introduction of the quick change-gear mechanism on lathes, an assortment of these gears was provided with every screw-cutting lathe, different sizes being employed for cutting threads of various pitches; hence, the name "change-gears." The gears of a milling machine, used to drive a dividing or index head from the table feed screw for such work as cutting spirals or helices, are also known as change-gears, and this term is applied to various other changeable gearing.

Quick Change-Gear Mechanisms: On many modern lathes, the changes of feed for turning and screw cutting are obtained by means of a system of gearing which enables the changes to be made rapidly, by simply shifting one or more levers. A table or index plate attached to the machine, shows what feed rates and pitches will be obtained for different positions of the levers. Quick change-gear mechanisms are also applied to various other types of machine tools.

Change-Gears for Thread Cutting. The change-gears for cutting threads of various pitches with an engine lathe, are usually shown by a table or index plate attached to the lathe, but the proper gears to be used can be calculated by the following rule.

Rule: First find the number of threads per inch that is cut when gears of the same size are placed on the lead-screw and spindle stud, either by trial or by referring to the index plate. Then place this number as the numerator of a fraction, and the number of threads per inch to be cut, as the denominator; multiply both the numerator and denominator by some trial number, until numbers are obtained which correspond to numbers of teeth in gears that are available. The product of the trial number and the numerator (or "lathe screw constant") represents the gear for the spindle stud, and the product of the trial number and the denominator, the gear for the lead-screw.

Channel. The name applied to a standard structural steel shape consisting of a web and two flanges projecting at right angles to the web and on the same side, thus forming a channel or U-shaped section. See Structural Shapes.

Channeling. The formation of irregular sections of sheet metal of indefinite length for use in the manufacture of metal furniture, automobile rims, shows cases, etc., in the small sizes, and for structural steel work, gutters, molds for cement forms, steel

car manufacture, and kindred uses, in the larger sizes, by means of rolling, is known as channeling. Sheet stock of any metal may be formed cold by channeling, and any thickness up to 1/4 inch may be worked without difficulty. The speed at which this class of work is handled varies from 50 to 90 feet per minute, according to the metal and the shape to be produced.

Chaplets. When the cores of foundry molds are not supported or held securely by suitable core-prints, and are likely to be moved from their proper position by the wash and lifting action of the molten metal, it becomes necessary to secure or anchor them with chaplets. These are made in a variety of shapes and sizes to meet the different conditions that may arise.

Chapmanizing. The process known as "Chapmanizing," is adapted particularly to the casehardening of the low-carbon and cheaper grades of steel, thereby eliminating, in many instances, the necessity for using expensive steels and elaborate heat-treatments. This process was developed by the Chapman Valve Mfg. Co., Indian Orchard, Mass. By applying this process to low-carbon steel, an almost glass-hard surface is obtained. This hardness penetrates to a reasonable depth, so that the surface is extremely hard even after grinding. The degree of hardness and the depth of the case can be regulated to suit the requirements of each job.

Charcoal. Charcoal is the residue consisting of impure carbon which is obtained by expelling the volatile matter from animal or vegetable substances. The most abundant source of charcoal is wood. Under average conditions, 100 parts of wood yield about 60 parts, by volume, or 25 parts, by weight, of charcoal. The modern methods of producing charcoal from wood consist in using a cast-iron retort in which the wood is heated in order to remove the volatile constituents. Valuable by-products are also obtained in this manner (wood alcohol, wood tar, etc.). The uses of charcoal in the industries are many. It is an important fuel, especially in many metallurgical processes; it is also important as a constituent of gun powder; it is used as a filtering medium; and it has the power of removing coloring matters from solutions, and is, therefore, used to some extent in laboratory practice. The actual specific gravity of wood charcoal is 1.5, but owing to its porosity it floats on the surface of water.

Charles' Law. The volume of a perfect gas at constant pressure is proportional to its absolute temperature. This is known as the "law of Charles." Let V = volume of gas at 32 degrees F., and V_1, the volume of the gas at any other temperature T_1, then:

$$V_1 = V\left(1 + \frac{T_1 - 32}{491.2}\right).$$

Charpy Test. The Charpy test for hardness consists of striking specially prepared specimens of work with blows that can be figured in foot-pounds. The hardness is not measured, but instead the shock-resisting qualities of the work are determined. See Impact Tests.

Charred Bone. A material frequently used in carburizing mixtures for increasing the carbon content of the surface of low-carbon steel, so that it may be casehardened. A mixture of 35 per cent of charred bone, 30 per cent of burnt leather, and 35 per cent of wood charcoal, by weight, is frequently used. See also Carburizers.

Chasers. A chaser is a form of threading tool having a number of teeth instead of a single point like the threading tools commonly used in connection with lathe work. There are three general classes of chasers; namely, hand chasers, threading tool chasers (which are rigidly held in a tool-holder and used like an ordinary lathe threading tool), and die chasers, such as are used in thread-cutting dies.

Chaser Throat: The leading side or corner of each chaser in a die-head is usually beveled. This beveled edge is known as the "throat" of the chaser and serves to begin the cut gradually when the die is first starting a thread and also as it advances. The throat of the chaser not only inclines relative to the axis of the die (or screw being cut), but it is given clearance back of the cutting edge in a circumferential direction. In some cases, the throat angle must be abrupt in order to cut a full thread close to a shoulder. Aside from a requirement of this kind, the throat should preferably be ground so that the work of cutting a thread to the full depth is distributed over at least two or three on the leading side of the die.

Chasing Dial. The thread-chasing dial, or thread indicator, which is attached to the carriage and has a worm-wheel meshing with the lead-screw, shows when to re-engage the half-nuts of the apron with the lead-screw when cutting screw threads which are not a multiple of the number of threads per inch on the lead-screw. If the half-nuts were engaged at random for taking each successive cut the tool might not follow the original cut.

Chattering. The term "chattering," as applied by machinists, means the formation of slight ridges or nicks upon a part that is either being turned, planed, milled, or ground. Chattering may be caused by the design of the machine, the nature of the work or its proportions, the care and adjustment of the parts of the machine, the methods of setting the work in the machine or of driving it, the shape of the cutting tool or the manner in which

it is set in the machine, or the speeds and feeds employed for cutting.

The action that occurs when a turning operation is accompanied by chattering is as follows: Either the tool or the work is momentarily deflected, causing slight changes in the depth of cut taken. This action occurs very rapidly as the part revolves, so that the surface, instead of being turned smooth, is covered with small ridges or corrugations. Chattering not only mars the turned surface, but quickly dulls the cutting edge of the tool. High cutting speeds tend, far more than slow speeds, toward producing minute and rapid vibrations in all parts of the machine, and, in order to prevent or absorb these vibrations, the members of the machine which support the tool and work should be massive, to secure the required rigidity. A common source of chatter can be eliminated by a systematic method of adjusting the working parts of the machine in order to eliminate unnecessary play or lost motion.

The principal cause of chatter marks on parts which are ground in cylindrical grinding machines is the vibration of the work, which may be due to a number of causes, such as a lack of proper support for the work, lack of rigidity in the machine and incorrect work speed.

Checking Engineering Drawings. After drawings have been completely finished and contain all the necessary dimensions, symbols, abbreviations, notes, etc., it is the general practice to check them. The object of checking is not only to locate any errors that may have been made in the dimensioning, but to discover defects of any kind which should be remedied. A competent checker may suggest changes in design or in the method of manufacture. The checking may be done by the chief draftsman or by one or more experienced draftsmen who have been assigned to this work. In smaller drafting-rooms, the draftsmen often check each other's drawings, but a man should not check his own drawing, if this can be avoided, because he is not so likely to detect his own mistakes as someone else.

The tracing is generally used when checking, although some prefer a blueprint from the tracing. When using a blueprint, all corrections or changes may be indicated on the print in red pencil, and all figures that are correct may be checked with, say, a yellow pencil. After all changes have been approved, the changes indicated in red are made on the original prints which are afterward compared by the checker with the blueprint to see if all changes have been made correctly. This checked blueprint may also be filed away for reference purposes in case there is any doubt as to who is to blame. After a tracing has been checked, the initials of the man checking it and the date should be placed

on a space provided. The checking of drawings should be done in a systematic way, and checking lists are often issued which show just what requires checking or, at least, the essential details of this work. These lists are prepared partly with reference to the product of the plant or the conditions peculiar to it, although many items found in checking lists apply regardless of the class of work.

Checking of Steel. The cracking or checking which sometimes occurs when grinding high-speed steel tools is said to be caused invariably by the use of cooling water while rough-grinding the tool. A practice recommended is as follows: Have the tool rough-forged to approximately the required shape; grind the tool slowly at first until it becomes warmed through, after which the grinding may be done rapidly without injury to the tool, but water should not be used when rough-grinding, as it tends to cause checking.

Checking Systems for Tools. See Tool Checking Systems.

Check-Nut. A check-nut or jam nut is used for binding or securing the ordinary nut screwed onto the end of a bolt. See Jam Nut.

"Check" Type of Gage. "Checks" are simply standards for the inspection of wear of working and inspection gages. They indicate when the gages are so worn by use that they are no longer suitable for the purpose for which they are intended. Checks may be used for a considerable number of gages, but are necessary in the case of many types, such, for example, as ring or snap gages which are too small to be measured by ordinary methods.

Check-Valves. Check-valves are designed to allow any fluid to pass through them in one direction only, any pressure in an opposite direction tending to immediately close the valve. Check-valves are made in several forms, including the globe check-valve, the swing check-valve and the ball check-valve. The ball type is designed particularly for use with heavy liquids, such as molasses or heavy oils. The particular advantage of the ball valve is that it opens readily and gives a free and unobstructed passage through the valve body, which is not likely to become clogged or obstructed by foreign matter. The boiler check-valve is located between the injector and the boiler, its function being to permit the passage of feed water to the boiler, without permitting any backward flow when the injector is not working. It is essential that the check-valve be tight and have the proper amount of lift. See Automatic Stop and Check-valves.

Chemical Affinity. The force which holds together the molecules of a substance. It is also known as chemical force.

Chemical Analysis. The resolution of complex bodies into their elements is termed *chemical analysis.* When only the constituent elements of a substance are determined, the analysis is said to be *qualitative;* but when both the constituents and the percentages of each are determined, the analysis is said to be *quantitative.* When the quantitative analysis determines the percentages of the compounds of which a substance is made up, it is said to be a "proximate analysis"; when the quantitative analysis determines the percentages of the elements of a substance, it is said to be an "ultimate analysis." For example, the proximate analysis of coal, which is the one usually made, shows the percentages of volatile matter, fixed carbon, moisture, sulphur, and ash; but the ultimate analysis will show the percentages of hydrogen, oxygen, carbon, nitrogen, etc. An analysis performed with the aid of a liquid solvent or reagent is termed a "wet" or "humid" analysis. A *reagent* is any substance used to effect a chemical change in another substance for the purpose of determining its component parts, or to ascertain its percentage composition. An analysis performed with dry reagents and heat is termed a "dry" analysis. The analysis of ores is usually termed "assaying"; this is divided into "wet assaying" and "fire assaying."

Chemical Change. A change in a substance which takes place within the molecules is called a chemical change. For example, if a magnesium rod is heated, it will combine with oxygen and form a white easily powdered substance known as "magnesia" or "magnesium oxide"; the magnesium has thus undergone a chemical change.

Chemical Equations. Chemical reactions are generally stated in the form of equations. In these, the symbols and formulas of the substance and the actions that take place are shown on one side of the equals sign and the result obtained is shown on the other. The equations show the relative number of molecules and atoms involved. They also indicate the weight of the quantities involved. As in the case of algebraic equations, the quantities on one side of a chemical equation must always equal the quantities on the other. Thus if the weight of one factor or product is known, the weights of all other factors and products may be calculated from the equation representing the reaction. As an example of a chemical equation, the following is given which indicates that calcium carbide and water forms calcium hydroxide and acetylene:

$$CaC_2 + 2H_2O = Ca(OH)_2 + C_2H_2.$$

Chemical Equivalents. Owing to the difficulty of determining atomic weights, some chemists have advocated the use of "chemical equivalents." The *equivalent* of an element is the rela-

tive weight of the element that combines with one part, by weight, of hydrogen. For example, 8 parts of oxygen, 35.4 parts of chlorine, 80 parts of bromine, and 16 parts of sulphur combine, respectively, with 1 part, by weight, of hydrogen; therefore, 8, 35.4, 80, and 16 are said to be the equivalents of these elements. However, many elements do not combine with hydrogen, and some combine with it in more than one proportion, so that the difficulty of determining the equivalent is as great as the difficulty of determining the atomic weight.

Chemical Formula. An abbreviation used to designate a chemical compound; it shows how many atoms of different chemical elements are contained in one molecule of the compound. For example, the chemical formula of ferric oxide is F_2O_3, which shows that one molecule of ferric oxide contains two atoms of iron, the symbol of which is Fe, and three atoms of oxygen, the symbol of which is O.

Chemical Reaction. Any chemical change that takes place is termed a *chemical reaction.* The change may be a rearrangement of the atoms of the different molecules, the combining of two or more molecules into one, two, or more different molecules, or the splitting up of one molecule into two or more molecules. All molecules entering into a reaction are called "factors"; those issuing from a reaction are called "products."

Chemistry. Chemistry is the science that treats of the composition of substances and the changes they undergo. Chemistry has in the past generally been divided into two classes, organic and inorganic, because of the belief that some substances could not be artificially produced; but, with modern developments in the laboratory, many of the substances classified as organic have been produced from inorganic matter. The division, however, is still maintained as a matter of convenience, and *organic chemistry* is commonly said to be the chemistry of carbon compounds, while *inorganic chemistry* is the chemistry of all other elements and compounds. This definition, however, is not absolutely true, as some carbon compounds, such as carbon monoxide, carbon dioxide, carbon disulphide, silicon carbide, and iron carbides that occur in cast iron and steel, are practically always considered as inorganic; while some substances, such as chloroform, that do not contain carbon, are treated as organic. Chemistry is also divided into *synthetic,* or the building up of more complicated from less complicated substances, and *analytic,* or the determining of the components of a substance. The term "synthetic" is also used for substances made by artificial means in the laboratory, to distinguish them from like substances obtained directly from plants or animals.

Cherrying. The term "cherrying" relates to the milling of circular or spherical impressions in dies as for example when a milling cutter is sunk to one-half its depth in milling out a circular recess. A *cherry* is a milling cutter, usually made integral with an arbor the length of which varies with the requirements of the work to be done. Many devices and attachments for both the milling machine and die-sinking machine have been devised to eliminate chipping and the difficult hand work of drop-forging dies, etc.

Chester Emery. A natural abrasive obtained from Chester, Mass., which is not considered to be of quite as high a grade as the imported Naxos and Turkish emery. It contains a large percentage of non-cutting elements; the crystalline alumina, which determines the cutting qualities, being only about 55 per cent of the total composition.

Chestnut Coal. A term indicating the grading of the coal as to size. This grade will not pass a screen of $\frac{3}{4}$-inch mesh, but will pass a screen of $1\frac{3}{8}$-inch mesh.

Cheval-Vapeur. Same as *Metric Horsepower.*

Ch'ien. A Chinese measure of weight, legalized in 1908, equal to 3.73 grams or 57.6 grains.

Ch'ih. A Chinese length measure, legalized in 1908, equal to 320 millimeters, or 12.6 inches.

Chilled Castings. A chilled casting is one which has been cooled suddenly by casting it in contact with some material which will rapidly conduct heat away from the surface of the casting. The effect is to produce a surface of great hardness which will withstand considerable wear. Such castings are used for many purposes, such as for railroad car wheels, rolls, jaws of crushing machines, stamps, etc. In the case of cast-iron chilled castings, the chill is always produced by iron in the mold. Either the complete mold is made of iron, or iron slabs called "chills" are imbedded in the mold, so that certain surfaces (those exposed to the greatest wear) are chilled. Thus, the tread of car wheels and the wearing surfaces of machine tool beds are often chilled to increase the life of the wheel or machine ways. A casting poured against a surface of solid iron may be chilled from $\frac{1}{8}$ inch to 1 inch in depth. When a casting has a heavy section which adjoins a comparatively light section, chills have been used, in special cases, to secure more uniform cooling between the heavy and light sections in order to prevent the formation of internal blow-holes.

Chills for Castings: Chills may be used as part of the mold or in the same capacity as a core. The patternmaker's job is to fit the pattern to the chill as they are rammed up together; if a

round hole is to be chilled, core-prints are fitted to the pattern and the chill is made with considerable taper so that it may be driven out. It is sometimes desirable to make sections of pipe to bolt together without finishing the flanges; and to do this, metal ends are used in the mold, not to chill the casting but to form a finished flange. In this case, the flanges are made long to form core-prints for the metal ends, the face sides of which are grooved with concentric V-grooves to give the packing a hold. The core is carried on an arbor that fits openings turned in the end pieces which are also drilled with holes through which the bolt hole cores are pushed.

Chimneys. The requirements of a chimney are that it shall provide sufficient draft to burn the required amount of fuel on the grate of a boiler in a given time, and also carry off the obnoxious gases. The strength of the draft depends upon the height of the chimney, while the volume of the gases to be carried off fixes the sectional area of the flue. The exact proportions depend upon the kind and amount of fuel to be burned, the design and arrangement of the boilers and connecting flues, and the altitude of the plant above the sea level. No universal formula has yet been devised which covers all of these conditions, so that it is more common in designing a chimney to use experimental data obtained from chimneys in actual use. As a rule, in ordinary boiler work the chimney lining need not be more than one-fifth of the height of the chimney, if the exhaust gases do not have a temperature over 800 degrees F. If the temperature of the exhaust gases is higher, the lining must extend higher inside the chimney.

The *draft* produced by a chimney is due to the comparatively high temperature of the furnace gases which pass up the chimney. As these hot gases are lighter than an equal volume of outside air, the pressure within the chimney is less than the atmospheric pressure surrounding the chimney; consequently, air from the outside naturally flows through the furnace and into the chimney and the necessary draft is thus obtained.

Chin. A Chinese measure of weight, legalized in 1908, equal to 596.8 grams or 21.05 ounces avoirdupois.

China Clay. An aluminum silicate found in nature as a fine white powder. It is used in paints for the protection of iron and steel against corrosion. It grinds in 28 per cent of oil.

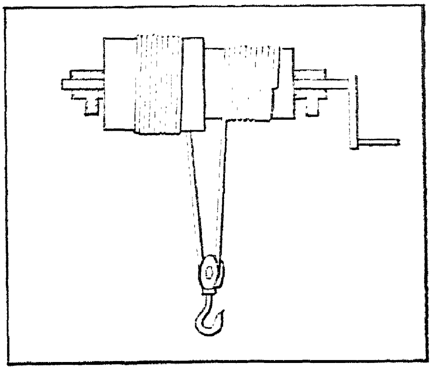
Chinese Alloys. There are a number of alloys known as Chinese bronze, Chinese copper, etc. These have somewhat varying compositions. Chinese bronze, according to one formula, contains 83 per cent copper, 10 per cent lead, 5 per cent tin, and 2 per cent zinc. Chinese white copper contains about 40 per cent cop-

per, 32 per cent nickel, 25 per cent zinc, and 3 per cent tin. The metal used for Chinese gongs contains 81 per cent copper and 19 per cent tin; this is practically the same composition as that used for bell metal, which is 80 per cent copper and 20 per cent tin.

Chinese Windlass. The Chinese windlass (see diagram) is of the differential motion principle, in that the resultant motion is the difference between two original motions. The hoisting rope is arranged to unwind from one part of a drum or pulley onto another part differing somewhat in diameter. The distance that the load or hook moves for one revolution of the compound hoisting drum is equal to half the difference between the circumferences of the two drum sections.

Ch'ing. A Chinese surface measure, legalized in 1908, equal to 614.4 ares or 15.18 acres.

Chip and Oil Separators. Chips from screw machines and other classes of machine tools requiring oil lubrication for the cutting tools, may contain considerable oil even after the chips have been drained by gravity. The average amount of oil on screw machine chips is about 3 gallons per 100 pounds, and by gravity draining only about 30 per cent of this oil is reclaimed; hence, oil extractors are commonly used in machine tool-using plants. These extractors operate on the centrifugal principle. The chips are placed in a perforated pan or basket which is rotated rapidly, thus causing the oil to fly out through the perforations. With these centrifugal oil extractors from 1 to 5 gallons of oil per 100 pounds of chips may be reclaimed. About 2 gallons per 100 pounds is a fair average, but the amount varies considerably, depending upon the extent of previous draining by gravity and the viscosity of the lubricant. By this centrifugal method practically all of the oil is reclaimed and the process requires only 2 or 3 minutes. Some centrifugal separators are driven by belt and others by a direct-connected electric motor, and the speeds vary from 500 or 600 R.P.M. up to about 1000 or 1200 R.P.M.



Chinese Windlass

Chip and Work Separators. The machines used for separating chips from screw machine products, etc., usually are either of the blower type which utilizes a blast of air for blowing the chips from the work, or the purely mechanical type which de-

pends entirely upon the reciprocating movement of a screen for separating the chips by a sifting process.

Chip Separators of the Blower Type: One chip and work separator of the blower or pneumatic type has a work-holding box which is placed in a vibrator. The vibrator spreads out the work and chips and the latter are blown through a hood while the finished parts drop into a pan. This type of machine is built in large and small sizes. The small separator may be used not only for screw machine products, etc., but for watch, clock and other small parts, and also for separating parts from sawdust after tumbling. Parts that are very small and light may be separated by means of an exhauster attachment. In operating this attachment, the material is placed in the work pan and pushed to the inlet opening in the elbow. The chips are then sucked up through the elbow and exhauster, and discharged through the hood, while the finished parts drop through a hole in the bench or table into a box. The lever is operated to regulate the air blast for both blowing and exhausting; the smaller the parts are, the less air is required.

Another blower type of separator operates in the following manner. The work and chips as they come from the screw machine or other machine tool, are put into a hopper at the top of the separator. This hopper is connected by a gate with an inclined slide, and both hopper and slide have a compound vibratory motion which spreads the work and chips out in a thin layer as they move down the slide after the hopper gate is opened. In this slide there is an opening through which the work drops into a tote pan. The chips, however, are prevented from falling through the opening and are floated over it by a draft of air from a centrifugal blower located beneath the hopper and slide. The machine is equipped with a hood to deliver the chips into a wheelbarrow.

Reciprocating Type of Chip Separator: One design of machine for separating chips from work, operates with a reciprocating motion derived from a crank and rod connected with a "shaker box" which contains the work and is reciprocated on the horizontal ways of the machine stand or base. The shaker box has a wire screen bottom, the mesh of the screen depending upon the kind of chips. This machine is intended for use in combination with an oil separator for separating chips from finished work, after the oil has been separated from both work and chips.

Separating Monel and Steel Chips: A magnetic device has been used successfully by one of the large manufacturers of electrical equipment for separating iron and steel chips from monel metal chips, thus effecting a large saving annually due to the reclaiming of the monel metal. Experiments in using the magnetic method were not successful at first, because the monel metal was picked

up by the magnet, but by using a rheostat on the magnetic separator and reducing the current to a minimum it was found that the iron and steel chips could be picked up and the monel chips dropped. During cold weather, congealing of the oil on the chips may interfere with clean separation because the oil holds the two metals together; however, this difficulty may be overcome by drying the chips prior to separation.

Chip Breaker. The term "chip breaker" indicates a method of grinding turning tools, that will break up the chips into short pieces, thus preventing the formation of long or continuous chips which would occupy considerable space and be difficult to handle. The chip-breaking form of cutting end is especially useful in turning with carbide-tipped steel turning tools because the cutting speeds are high and the chip formation rapid. The chip breaker consists of a shoulder back of the cutting edge. As the chip encounters this shoulder, it is bent and broken repeatedly into small pieces. Some tools have attached or "mechanical" chip breakers which serve the same purpose as the shoulder.

Chip Crushing Machine. This type of machine is used for crushing metal chips and scrap so that a much larger amount may be stored or shipped in a given space; moreover, by crushing the chips a larger percentage of oil can be reclaimed. One machine on the market has a capacity of about 5 tons of steel chips per eight-hour day, and another machine has about the same tonnage capacity per hour.

Chips, Briquetting Metal. See Briquetting Metal Chips.

Chisels, Metal-Cutting. See Cold Chisels.

Chlorine. Chlorine is a gaseous chemical element of greenish-yellow color. Its symbol Cl; atomic weight, 35.46; specific gravity, 2.49 (air = 1); liquefying point, —34 degrees C. (—29 degrees F.); and solidifying point, —102 degrees C. (—152 degrees F.). It is never found in nature in an uncombined condition, but is widely distributed in combination; it is one of the constituents of common salt. Combined with hydrogen, chlorine forms hydrochloric acid. Chlorine is used for many purposes in the industries, and many processes have been devised for its production.

Chlorine-Proof Cement. A luting material used in electrolytic and chemical plants, which will withstand the action of chlorine, as well as that of acids and alkalies. It consists of one part Portland cement, one part powdered glass, one part silicate of soda, and a small amount of powdered slate. Linseed oil made into a paste with fireclay will also prove impervious to chlorine for a short time.

Chromatic Speed Range. The "chromatic speed range" for speed-changing mechanisms is based on the square root of 2, or 1.4142. This range is simply a geometrical progression with a ratio of 1.4142, or a smaller ratio may be used, as 1.189, which is the square root of 1.4142, or the fourth root of 2. The logarithmic scale gives a number of values the adoption of which as standards in designing speed-changing mechanisms has been proposed. These values are approximately as follows: 4.75, 5.67, 6.75, 8, 9.5, 11.3, 13.5, 16, 19, 22.6, 26.9, 32, 38, 45.2, 53.8, 64, 76, 90, 108, 128, 152, 181, 215, 256, 304, 362, 430, 512. The ratio of the geometrical progression, in this case, is 1.189, although the increment of change might be any power of 1.189. With this speed range back-gear ratios of 2, 4, 8, and 16, according to the range desired, could be employed. This point is considered important, because, on some classes of machines, especially lathes, the back-gear ratio can be utilized conveniently for obtaining coarse leads.

Chromel. Chromel is the trade name for a high-grade alloy containing, in its best grade, 80 per cent nickel and 20 per cent chromium. Another grade contains 85 per cent nickel and 15 per cent chromium, while still a third grade contains approximately 61 per cent nickel, 25 per cent iron, 3 per cent manganese, and 11 per cent chromium. All other elements are classed as impurities and are held down to a minimum. Chromel alloys have an electrical resistance from fifty to sixty-five times greater than that of copper, depending on the grade of the alloy, and they also have a very high resistance to heat.

The behavior of this alloy under high temperatures makes it suitable for use as a heating element in all kinds of electrically heated devices, from electric toasters to furnaces used for heating steel preparatory to hardening or forging. Iron-free chromel may be found in use in the thermo-couples of nearly all pyrometers that work at a temperature up to 2200 degrees F. This alloy is said to be mainly responsible for the rapid growth of the electric heating industry in which it is used for heating apparatus that operates at temperatures between 1500 and 2200 degrees F. The third grade of the alloy, in which iron is an ingredient, is used extensively in the construction of flat-irons, ovens, and heating devices that operate below a temperature that does not exceed the oxidizing point of the alloy.

Chrome Iron. The term "chrome iron" is sometimes applied to an alloy consisting primarily of iron and chromium. Alloys of this kind and containing from 27 to 30 per cent chromium were developed originally for high-temperature installations, but they also resist corrosion, nitric acid and most organic acids. See Duraloy.

Chromium. Chromium is one of the metallic chemical elements; its chemical symbol is Cr, and its atomic weight, 52.0. The specific gravity of the pure metal is 6.9, but the commercial metal has a specific gravity of about 6.5, making its weight per cubic inch equal to 0.235 pound. The melting point of chromium is 1510 degrees C. (2750 degrees F.). Its electrical conductivity (silver = 100) is 16. Chromium is an intensely hard, brittle metal, whiter and more lustrous than iron in its appearance, but slowly oxidizing in the air. It does not occur free in nature, but is found in a number of different minerals. The mechanical importance of chromium is as an alloying metal for steel. *Chromium steels* have remarkable qualities as regards tensile strength and high elastic limit, when properly heat-treated. Chromium, when used in the manufacture of chromium steel, is introduced in the form of a chrome-iron ore, also known as *chromite* or *chromic iron.* This is the chief commercial source of chromium and its compounds.

Chromium Plating. Chromium plating is an electrolytic process of depositing chromium on metals either as a protection against corrosion or to increase the surface wearing qualities. In general, the equipment used is similar to that used for other kinds of electro-plating, but the results are more affected by the temperature of the bath and the current density. The hardest deposit of chromium is obtained at the highest current density that can be applied without "burning." A temperature for the bath of about 45 degrees C. (113 degrees F.) and 100 amperes per square foot gives a very bright deposit. The "throwing power" of the chromium plating process is relatively poor, which means that it is comparatively difficult to deposit the chromium in recesses or on parts of irregular shape. A chromium plated surface can be polished so that it will be more brilliant than nickel and have practically the same reflecting power as a high-grade mirror. A chromium coating can be deposited up to at least 0.005 inch thick, which is thicker than ordinarily required in commercial work; brightness of surface is sacrificed with increase of thickness. Chromium plated surfaces are usually hard and resist tarnishing and corrosion.

Chromium plating can be applied to practically all commonly used metals, with the exception of silver and aluminum, and even aluminum alloy die-castings of certain compositions have been successfully plated with chromium. Only two acids, muriatic and hydrochloric, attack chromium plating and its bright lustrous finish is unaffected by heat up to temperatures of 700 degrees F. The melting point is about 3000 degrees F.

Hardness of Chromium Plate: Although it is difficult to gage accurately the hardness of chromium plating, scratch tests indi-

cate that it has about the same hardness as the sapphire. Glass can be scratched readily with the edge of a piece of brass strip stock which has been chromium plated, whereas a similar piece which has been nickel plated will simply slide over the glass.

Chromium Plated Cutting Tools: Metal-cutting tools which have been built up on their cutting edges by chromium plating have given excellent results. A 3/16-inch reamer used for reaming holes in a monel metal part, for instance, was brought up to the required size by chromium plating. In this case 0.001 inch of metal was put on. The reamer thus treated shows no sign of wear even though it has already produced several times as much work as the best reamer previously obtainable.

Among the various types of cutting tools which have been chromium plated are taps and forming tools. Manufacturers of bakelite and other phenol products have, in some instances, found it profitable to have their cutting tools chromium plated. The hardness, resistance to corrosion and the smooth finish of chromium plating, which lessens chip clogging, makes chromium plated taps especially well adapted for use on bakelite parts. Chromium plated files have proved excellent for use on soft metals, as they do not clog or load up as quickly as unplated files and hold their edge exceptionally well. Chromium plated rivet spinning tools have been found to stand up from ten to fifteen times longer than the hardest unplated steel tools.

Dies and Metal Spinning Tools: Dies for molding or forming bakelite products of simple form have been found to give longer service and produce a better finish when chromium plated. The depth of plating for dies of this kind is about 0.002 inch. The low coefficient of friction of chromium plated surfaces undoubtedly contributes much to the success of certain metal-cutting or metal-working tools, such as punches and dies for drawing seamless tubes and shells.

Building Up Worn Plug Gages: Plug gages which have been worn undersize can be built up by chromium plating and then lapped to size. Any amount of metal up to 0.004 or 0.005 inch can be added to a worn gage. Chromium oxide is used in lapping chromium plated gages, or other parts, to size and for polishing. When the chromium plating of a plug gage has worn undersize, it may be removed by subjecting it to the action of muriatic acid. The gage is then built up again by chromium plating and lapped to size. When removing the worn plating the gage should be watched carefully and the action of the acid stopped as soon as the plating has been removed in order to avoid the roughening effect of the acid on the steel.

Cleaning Work to be Plated: Work which is to be chromium plated must be clean and free from dirt or grease, the same as

when any other finish is to be applied. Parts which have been cleaned for finishing by nickel plating are generally sufficiently well prepared for chromium plating. An effective method of cleaning greasy or dirt covered parts is to wash them in a 5 per cent sulphuric acid solution.

Chromium-Vanadium Steel. Alloy steels of this class, according to the S.A.E. specifications, contain 0.80 to 1.10 per cent chromium; 0.18 per cent vanadium preferably, and a minimum of 0.15 per cent; 0.60 to 0.90 per cent manganese in most cases; a maximum of 0.04 per cent phosphorus, and the same maximum of sulphur; and a carbon content ranging from 0.15 to 1.05 per cent, depending upon the class of steel and its application. Most chrome-vanadium steels contain from 0.20 to 0.50 per cent carbon. Many heat-treated forgings are made from these steels.

Chromizing. Chromizing is somewhat similar to the process of calorizing. It consists of packing the material to be treated in a powdered mixture of alumina and chromium—45 per cent of alumina and 55 per cent of chromium, by weight. The material is usually packed into a tube of iron, which is then heated to from 1300 to 1400 degrees C. in hydrogen, vacuum, or some neutral atmosphere. Chromizing has been used on turbine buckets in order to protect them against corrosion. By casehardening and heat-treatment chromized iron may be made very hard.

Chuck Closer. An "automatic" chuck closer is frequently used on bench lathes in connection with a turret and double-tool cross-slide, when operating on bar stock. This device is used in place of the regular draw-in spindle, and closes the collet chuck by simply throwing over a hand lever. The chuck-closing mechanism is applied at the rear end of the spindle and takes place of the usual handwheel. It enables the machine to be run continuously, as the work may be gripped or released while the lathe is in motion.

Chucking Machines. Some turret lathes are used exclusively for operating on bar stock which is fed through the hollow spindle and is held by some form of collet chuck located in the end of the spindle, whereas other machines are equipped either for handling bar stock or larger work which must be held in a regular chuck that is screwed onto the spindle. There are also turret lathes which are not arranged for turning parts from bar stock, but are designed exclusively for machining castings or forgings which must be held in a chuck that is screwed onto the spindle. Lathes of this latter class are frequently called *chucking* machines, owing to the fact that the work is always held in a chuck.

Multiple-spindle Chucking Machine: This is an automatic machine provided with a number of spindles, usually four or five, which carry and revolve the tools, while the work being machined is held stationary in a multiple-chuck turret which holds each part in line with one of the spindles and which is automatically indexed, so that the work passes from one spindle to another until it is finished. This type of machine is especially adapted for boring, reaming, and facing operations on castings or forgings which can readily be held in chuck jaws.

Chucking Reamers. Reamers of this class are so named because they are used largely for reaming parts held in the chuck of some machine such as an engine lathe or turret lathe. Chucking reamers are made in two general types: *fluted* chucking reamers and *rose* chucking reamers. The fluted type is used for enlarging drilled holes and finishing them true to size; the rose type is used for enlarging cored or drilled holes and is so constructed that a considerable amount of metal can be removed by it. See Fluted Chucking Reamer and Rose Chucking Reamer.

Chucks. Chucks of various designs and types are used on different classes of machine tools, either for holding a part while it is being operated upon or for holding some form of cutting tool. The chucks that are used on lathes and other types of turning machines hold and rotate the work, whereas the chucks of drilling machines hold and rotate drills, counter-bores, and other tools. Chucks vary greatly both in regard to their size and design. Some are of special construction and are intended for a limited class of work or for holding one particular part, although most work-holding devices of the latter class are known as jigs or fixtures, rather than chucks. The term "chuck," as applied in the machine shop, usually means a device which not only holds but rotates either the work or a cutting tool, although there are exceptions as, for instance, in the case of planer chucks which are attached to the planer table and travel with it. Most work-holding devices which are classified as chucks have gripping jaws that are adjustable in order to adapt the chucks for holding parts or tools of different sizes. These jaws are operated either by screws, by a combination of screws, or a spiral scroll and gearing, by compressed air, or by the engagement of conical surfaces which serve to move the chuck jaws radially by a wedging action. There are also magnetic chucks which do not require jaws, as the work is held by magnetic force instead of by mechanical means.

Chucks, Air-Operated Type. Air-operated chucks are used on some turret lathes, especially when a rapid power method of chucking is essential to economical production. Chucks operated

in this way are especially desirable when the machining operation is rapidly performed and the work is required in large quantities. Such equipment is particularly adapted for brass work.

Chucks, Gear. Special chucks are commonly used for holding gears, especially when grinding the bores of heat-treated gears to insure accuracy between the bore and the teeth. The chuck may be designed to hold the gear (1) by contact at the pitch line; (2) by contact at the bottom of tooth spaces; (3) by contact with the outside diameter or tops of the teeth. The pitch-line contact may be obtained by means of rolls which serve as gripping jaws. Another type of chuck has accurate gears which serve as jaws and are tightened into mesh with the gear to be ground. The root control, or contact at the bottom of the tooth spaces, is obtained by means of special jaws which are narrow enough to bear only on the root. Some gear chucks for bevel gears have tapering pins for pitch-line contact and others, jaws for engagement at the bottoms of the tooth spaces. A third method consists in clamping the bevel gear against a master gear which meshes with the gear to be ground.

Chucks, Lathe. There are three classes of chucks ordinarily used on the engine lathe, known as the independent, universal, and combination types. The *independent chuck* is so named because each jaw can be adjusted in or out independently of the others by turning the jaw screws with a wrench. The jaws of the *universal chuck* all move together and keep the same distance from the center, and they can be adjusted by turning any one of the screws, whereas, with the independent type, the chuck wrench must be applied to each jaw screw. The *combination chuck,* as the name implies, may be changed to operate either as an independent or universal type. The advantage of the universal chuck is that round and other parts of a uniform shape are located in a central position for turning without any adjustment. The independent type is, however, preferable in some respects, as it is usually stronger and adapted for holding odd-shaped pieces, because each jaw can be set to any required position. The *collet chuck* is another class which is commonly applied to tool-room lathes, turret lathes, bench lathes, etc., usually for holding rods or bar stock, which is inserted through the hollow spindle of the machine, so that the end projecting beyond the chuck may be operated upon.

Chucks, Magnetic. Magnetic chucks are unexcelled for holding a large number of small parts at one time for grinding and are also adapted for a wide range of work. They are made in a variety of sizes and shapes, the form depending upon the type of grinding machine and the shape of the work. The magnetic

chuck is a special form of electromagnet which is connected by wires and a control switch with an electric power circuit. The surface, against which the work is held, has a series of positive and negative holes which are separated by an insulating material. When in use, the chuck is clamped onto the table of the grinder, and the work is held by magnetic force when the current is turned on. The rectangular magnetic chuck is the form used on surface grinders of the reciprocating type. Magnetic chucks are made in many different styles and shapes. Some are so arranged that the clamping face can be set at any angle for taper grinding and others have faces that are vertical. There is also the rotary type and other special designs. The rotary form is used when a continuous rotary movement is required, instead of a reciprocating motion.

Chucks, Quick-Change Type. The quick-change collet chuck is adapted for both drilling and tapping operations. With one arrangement the drill or tap is held in a collet and, in order to mount the tool in the chuck ready for use, it is merely necessary to grasp a knurled collar and hold it back against the rotation of the spindle. This causes a pair of retaining dogs to be drawn back into the body of the chuck so that the collet can be slipped into place. The knurled collar is then released and the action of a spring forces the dogs inward, so that they engage a groove in the collet and secure it in the chuck.

Chucks, Vacuum. See Vacuum Chucks.

Cincinnati Plan. A system of engineering education in which the students, taking engineering courses at a technical college, work alternate weeks in regular manufacturing shops and in the school.

Cinnabar. Cinnabar is a very heavy mineral composed of red sulphide of mercury, found in California, Mexico, Spain, Hungary, Chile, and several other places. It is the principal and most valuable of the commercial mercury ores.

Circle. A plane surface bounded by a curved line known as the *periphery* or the *circumference,* all points of which are at an equal distance from a point within the circle known as the "center." The term "circle" is also used with reference to the periphery or circumference only, without reference to the plane surface enclosed by the circumference. In the mathematical sense of the word, this usage is not correct. The circular line is the "periphery," and the area enclosed is the "circle."

Circle Dividing. If there are six divisions, the dividers may be set to the radius of the circle. For any other number of divisions, the distance between the dividing points may be deter-

mined by the following rule: Divide 360 by the number of divisions required to obtain the angle between centers of the spaces; find the sine of one-half this angle (by referring to a table of sines) and multiply it by the diameter of the circle upon which the centers of the spaces are to be located. Assume that twenty equally spaced centers are to be located on a circle 10 inches in diameter; then the angle between the centers equals $360 \div 20 = 18$, and the sine of one-half this angle, or 9 degrees, is 0.15643; therefore the distance between the divider points equals $0.15643 \times 10 = 1\text{-}9/16$ inch, approximately.

Circuit-Breakers. A circuit-breaker is a device for automatically opening an electric circuit when a predetermined abnormal condition exists in the circuit in which the circuit-breaker is connected. Thus, it is generally designed to trip under one of the following conditions or some combination of them: Overload, underload, over-voltage, low voltage, and reverse current. The automatic tripping of a circuit-breaker is accomplished by applying or releasing the power of an electromagnet which is excited by current flowing through a coil of wire, or its equivalent, surrounding at least one pole of a magnetic circuit. The magnet coils may be of either one of two classes—current or potential—depending upon the manner in which the coils are connected in the circuit. There are two main types of circuit-breakers in use: the air circuit-breaker and the oil circuit-breaker.

Air Circuit-breaker: In this type the circuit is broken in air or gas and various means are taken to prevent excessive arcing when heavy currents are interrupted. Thus, (1) an auxiliary set of carbon contacts may be used to take the final arc, (2) a magnetic "blowout" or intense magnetic field may be used to extend the path of the arc, thus aiding its rupture, (3) a de-ionizing device may be used which breaks up the single arc into a number of small arcs between de-ionizing plates, or (4) a blast of air or carbon dioxide may be used at high pressure to blow out the arc. Small air circuit-breakers have been widely introduced for use in place of plug fuses for the protection of lighting circuits. Large sizes are used in power circuits. See also: Switches, Air-break Type.

Oil Circuit-breaker: In this type of breaker the arc is interrupted under oil which provides a quenching effect. A de-ionizing element may be used to aid in the rapid extinguishment of the arc. See also: Switches, Oil Type.

Circular File. The circular form of file is intended more particularly for filing soft metal, such as aluminum, solder, babbitt, etc. This type of file is simply a steel disk on the sides of which

teeth are cut. When the file is in use, it is mounted on a spindle like a grinding wheel and is rotated by power. A circular file 14 inches in diameter and 1 inch thick is rotated at a speed of about 200 revolutions per minute. The part to be filed is held against the side of the revolving file. There are several annular rows of teeth, the teeth in adjacent rows inclining in opposite directions. The grade of cut is varied to meet different requirements.

Circular Inch. The area of a circle 1 inch in diameter. One circular inch is equal to one million circular mils, or 0.7854 square inch.

Circular Measure. The system of angular measurement in which the *radian* is used as a unit. This system is generally used in theoretical investigations and in formulas relating to revolving bodies. See Radian.

Circular Mil. In measuring diameters and areas of electric wires, use is frequently made of the surface measurement *circular mil.* A circular mil is the area of a circle 0.001 inch in diameter; one circular inch equals the area of a circle 1 inch in diameter; hence, 1 circular inch equals 1,000,000 circular mils. A circular inch equals 0.7854 square inch.

Circular Pitch. The *circular pitch* of a gear tooth is the distance from the center of one tooth to the center of the next, measured along the pitch circle. The circular pitch system is applied, as a general rule, only to gears with cast teeth which are not afterwards finished or cut, and to very large pitches. For cut gearing, *diametral pitch* is used almost exclusively, especially when the pitch is not coarser than one diametral pitch. When the pitch diameter and the number of teeth of a gear are known, the circular pitch is found as follows:

$$\text{Circular pitch} = \frac{\text{pitch diam.} \times 3.1416}{\text{number of teeth}}$$

Circumference. The curved line which forms the boundary line of any circular, elliptic or oval surface; specifically, the periphery of a circle.

Cistern Barometer. An instrument for measuring the pressure of the atmosphere, consisting of a glass tube about 36 inches long, hermetically sealed at the upper end at which a vacuum is formed, the remainder of the tube containing mercury. The tube is placed with its open lower end in a cistern or vessel containing mercury, the pressure of the atmosphere being measured by the difference in the height of the mercury in the tube and in the cistern.

Citroen Gear. This type of gear might be described as a double herringbone form, as the teeth have a double wave formation such as would be obtained by placing two herringbone gears together. Gears of this type are used to a very limited extent as the herringbone gear has advantages in regard to cutting, and is, at least, equal to the Citroen gear from a practical or operating point of view.

Clack Valves. Pump valves of the *clack* or *clapper* type are hinged on one side so that they open and close like a door. The pivot of the hinge sometimes has an elongated hole so that the valve can lift at the hinged end so as to obstruct the flow of liquid as little as possible. Many valves of the clack form are of metal and have leather faces. When two clack valves are hinged at the center of a valve-seat, the term "butterfly" valve is often used. The *flap valve* is similar to a clack valve, except that it is fastened to one side of the valve opening instead of being hinged, and is formed of material that has sufficient elasticity to bend far enough to give the required port opening. These valves are usually made of rubber.

Clam-Shell Brake. A block brake provided with two blocks acting one on each side of the brake pulley. It is often used in place of a band brake, over which it possesses the advantage of even wear on the blocks and of a positive release, but it does not have as great a gripping power as a band brake.

Clark Cell. A primary cell or battery, known as a "standard" cell, used for obtaining a certain standard value of electromotive force under given conditions. It consists of a glass container mounted in a metal case, having insulated binding posts connected to platinum terminals. In one form, mercury, which is the negative electrode, is placed at the bottom of the cell, and a paste of mercurous sulphate and zinc sulphate is placed upon the mercury, the zinc plate, which is the positive electrode, being partly immersed in it, and then saturated zinc sulphate solution is put on top, the latter acting as the electrolyte while the paste acts as the depolarizer. The surface is usually covered with cork and the cell sealed. Platinum wire led through the bottom of the cell forms the terminal for the negative electrode, and insulated wire led through the cell forms the terminal for the positive electrode. The electromotive force is 1.4322 volts at 15 degrees C. (59 degrees F.).

Clay Crucible. A pot or container used in the steel industry in the manufacture of crucible steel, having a capacity of from 75 to 100 pounds of metal. Clay crucibles are made of a high quality of clay mixed with about 5 per cent of powdered coke.

They must be heated slowly to prevent cracking, and must be recharged while hot.

Cleaning Machines. Machines for cleaning and drying screw machine parts, stampings, etc., are made in several different designs. One machine consists of a revolving horizontal cylinder through which the parts pass during the cleaning or drying operation. As the parts pass from a chute into one end of the cylinder they are moved along by a helical or screw-shaped conveyor and the cleaning solution is scooped up from a tank below and poured on to the work. As the cylinder rotation continues, the work advances and is further cleansed by fresh solution and finally, when cleaned, reaches a perforated section of the cylinder. The solution then drains back into the tank. The parts are next rinsed with water and then pass into a larger perforated section where they are dried by means of hot dry air obtained by means of steam coils and a blower. Finally the parts pass out at the discharging end, the entire operation having been continuous and automatic.

Cleaning Metals, Electrochemical. See Electrochemical Cleaning.

Cleaning Solution, Soda. See Soda Cleaning Solution.

Clearance. "Clearance" is a term signifying the difference between working parts to admit of motion and lubrication. In other words, the clearance is the space between adjacent parts, whether this space is allowed merely to avoid interference, or in order to obtain definite classes of free fits. The clearance allowed between different parts is governed by the conditions under which the parts are to work.

Clearances are vital factors in interchangeable manufacturing. Fits can be secured without interchangeability, but the latter cannot be maintained without proper clearances. It is self-evident that a certain space must be left between operating parts. The minimum clearances should be as small as the assembling of the parts and their proper operation under service conditions will allow. The maximum clearances should be as great as the functioning of the mechanism permits. The variation between a maximum and a minimum clearance determines the manufacturing tolerance. It is clear, then, that determining at the outset the permissible clearances establishes also the extent of the tolerances which control the final inspection.

Clearances should be one of the principal considerations in developing the manufacturing design. This design should aim to allow the greatest possible amount of clearance between companion parts. The more the design lends itself to this end, the greater the economy of manufacture and the greater the degree

of interchangeability obtainable. In determining which parts of a mechanism can be made interchangeable, this matter of permissible clearances plays the largest part. A mechanism which is so designed that it cannot permit fairly liberal clearances is not a suitable one to be manufactured on a strictly interchangeable basis. Every operating part of a mechanism must be located within reasonably close clearances in each plane. After such requirements of location are met, all other surfaces should have liberal clearances, unless the factor of strength is the controlling one.

Clearance Air. The air which remains in the cylinder of an air compressor when the piston is at the extreme end of the stroke, and which cannot be expelled on account of the clearance between the piston and the cylinder head is known as clearance air. The clearance in air compressors commonly varies from 1 to 3 per cent of the piston displacement.

Clearance Drill. When a machine screw or cap-crew is used to fasten one machine part to another, the hole in the untapped part is drilled slightly larger in diameter than the outside or body diameter of the screw. This is done in order to provide a slight amount of clearance; hence, the drill used is known as a clearance drill. Assume that No. 6 machine screws are to be used for attaching a plate to a casting. The outside diameter of this screw is 0.138 inch, and the size of the clearance drill might be No. 27 or No. 25.

Clearance for Cutting Tools. In order that the cutting edge of a turning tool, drill, milling cutter or other edged tool for metal cutting, may work without interference, it must have clearance; that is, the surface below or back of the cutting edge must be ground to a certain angle so that it will not rub against the work and prevent the cutting edge from entering the metal. This clearance should be just enough to permit the tool to cut freely. A clearance angle of 8 or 10 degrees is about right for lathe turning tools. A turning tool for brass or other soft metal, particularly where considerable hand manipulation is required, could advantageously have a clearance of 12 or 14 degrees, as it would then be easier to feed the tool into the metal; but the clearance for various classes of metal-cutting tools should be just enough to permit them to cut freely. Excessive clearance weakens the cutting edge and may cause it to crumble under the pressure of the cut. The angle of clearance is about 4 or 5 degrees for planer tools, which is much less than that for lathe tools. This small clearance is allowable because a planer tool is held about square with the platen, whereas a lathe tool, the height of which may be varied, is not always clamped in the same positi

A lathe tool also requires more clearance because it has a continuous feeding movement, whereas a planer tool is stationary during the cut, the feed taking place just before the cut begins.

Clearance in Engine Cylinders. The clearance is the space between the cylinder head and the piston, when the latter is at the end of its stroke; it also includes that portion of the steam port between the valve and the cylinder. Clearance is usually expressed as a percentage of the piston-displacement of the cylinder, and varies in different types of engines. Ordinarily the percentages are about as follows: For Corliss engines, 1.5 to 3.5; engines for medium speeds, 3 to 8; high-speed engines, 4 to 10. A large clearance is evidently objectionable, because it represents a space which must be filled with steam at boiler pressure at the beginning of each stroke, and from which but a comparatively small amount of work is obtained. As compression increases, the amount of steam required to fill the clearance space diminishes, but, on the other hand, increasing the compression reduces the mean effective pressure.

Cleveland Grip Sockets. The grip socket known as the *Cleveland grip socket* is designed to hold and drive taper shank drills and other tools provided with taper shanks. A groove is milled in the shank of the drill or tool and a key which is let into the body of the socket fits into the groove and is locked securely in place by turning a revolving collar one revolution. When the key is locked, it is impossible for the tool to slip in the socket or to be pulled out until the collar is turned back again to release the key.

Climb-Cut Milling. In milling, the feeding movement and cutting movement are in *opposite* directions, as a general rule. This is sometimes known as the "normal" or "conventional" method of milling to distinguish it from the climb-cut method. The term *climb-cut* or *climb* milling means that the feeding movement of the work and the cutting movement are in the same direction. Several advantages are claimed for climb-cut milling, assuming that conditions are favorable to its application. One important advantage cited is that the cutter life is increased and at the same time higher speeds and feeds may be employed. When the cutter rotation is against the feeding movement (as in the conventional method) the cutting edge of each tooth rubs against the work or rides upon it momentarily before beginning to cut, which results in greater dulling of the cutter than when each cutting edge enters the metal at the top of the cut or at the point of greatest chip thickness. The advantage of the climb-cut method is said to be even greater for the harder materials,

although there may be an exception when castings have a hard sandy scale.

Climb-cut milling has another important advantage in that it enables pieces that are difficult to clamp securely in a fixture or on the machine table to be milled efficiently. The downward action of the cutter teeth in climb milling such pieces tends to seat them firmly in the holding devices. Cutters used in the conventional manner would tend to lift the pieces from their seats and might make the operation impractical. It is evident that a machine used for climb-cut milling must be in good condition and be so constructed that the machine table will resist the cutting forces in either direction. Any play or lost motion which would permit the cutter to climb into the work faster than intended would, of course, be objectionable.

Clock Brass. A brass suitable for the gears in clocks, containing about 60 per cent of copper, a small percentage (not exceeding 1.5 per cent) of lead, and the remainder zinc.

Closed-Circuit Oiling. A method of bearing lubrication generally used for high-speed work, in which the oil is used over and over again. After dropping off from the journal to a collecting reservoir, the oil is filtered and used again by being automatically supplied to the journal at a suitable point. A cooling arrangement is sometimes fitted to the reservoir, so as to remove the heat from the oil.

Closed Feed-Water Heater. A device in which the feed water for boilers is heated by passing it through a series of brass or copper tubes surrounded by steam. There is no intermingling of the feed water and the exhaust steam used for heating it.

Closer or Step Chuck. See Step Chuck.

"Cloudburst" Steel-hardening Process. The super-hardening of parts by means of the "Cloudburst" process is as follows: A part made of hard steel is immersed in balls which move about at a high velocity, striking each other and the part in rapid succession. This produces a thin super-hardened layer on the part analogous to that obtained on automobile gears and other parts as they become worn in service. It has been found that after the layer has been started, the velocity of the balls can be increased and this will increase the hardness and thickness of the layer, the layer resisting indentation. The super-hardened layer gradually decreases in hardness throughout its thickness, and as there is no abrupt change in hardness, the layer has no tendency to scale. The degree of hardness that can thus be produced depends upon the super-hardening capacity of the steel. The ball velocity required to produce the hardness is determined by

experience. The initial ball velocity is so adjusted to the hardness of the work that it is just enough not to indent the surface. It follows, then, that if any part of the work is soft, its surface will be indented and roughened. This has resulted in a process by means of which large quantities of hardened articles can be tested for hardness, all at once and all over, without marking them except on soft spots.

Cluster Gears. The term "cluster gears" is applied when two or more gears are formed on one solid piece. Cluster spur gears are commonly used in automobile transmissions and other geared speed-changing mechanisms because they are stronger and more compact than single gears fastened together.

Clutches. A clutch is a form of coupling which is designed to connect or disconnect a driving or driven member for starting or stopping the driven part. A clutch consists principally of two main sections which are engaged or disengaged either at will by a hand-operated controlling device, or automatically by the action of some power-driven mechanical apparatus, such as a cam connected by suitable means with the shifting clutch member. There are several distinct types of clutches which are made in a great variety of designs. The common types of clutches may be divided into two general classes; namely, (1) those having teeth which interlock, or positive clutches, and (2) those which transmit motion from the driving to the driven part of the clutch by frictional contact.

When motion is transmitted from the driving to the driven parts of a clutch simply by frictional contact, the load may be started gradually and without shock, such as often occurs when a positive clutch is engaged. The different types of friction clutches vary in regard to the form of the friction surfaces and with respect to the kinds of material used to obtain sufficient frictional resistance. The frictional surfaces may be either conical or cylindrical, or in the form of one or more flat rings or disks.

Conical Clutches: A conical clutch is so designed that motion is transmitted by the frictional resistance of engaging conical surfaces. The effectiveness of any friction clutch as a transmitter of power varies with the coefficient or degree of friction between the engaged surfaces. The frictional surfaces may both be of metal, but, in many cases, one member has a metal surface and the other is partially or entirely covered with some material such as leather or an asbestos fabric. The cast iron and leather combination is common, and pieces of cork inserted in holes drilled in one member is another common method of increasing frictional resistance. It is common practice to maintain the driv-

ing and driven members of friction clutches in engagement by means of springs which are compressed in order to release the clutch. The angle of the conical surfaces is usually about 12 or 13 degrees. The conical type of friction clutch is simple in construction but rather bulky or large when compared with other types of equal capacity as transmitters of power.

Expanding Type of Friction Clutch: The radially expanding type of clutch is a form that has been widely used, the details of the design being varied more or less. A typical design consists of an outer casing in which there are two expanders or segment-shaped pieces connected by right- and left-hand screws, respectively. These screws are attached to levers, which, in turn, are connected to the sliding sleeve, by links, thus forming toggles between the sleeve and the screws. The two expanders and the toggle mechanism are caused to revolve with the shaft by a central driving hub. The clutch is operated by shifting the sliding sleeve and toggles; this movement turns the screws having right- and left-hand threads far enough to either expand the inner members tightly against the outer casing or to withdraw them from frictional contact. The expanders may be lined with maple grips, to increase the frictional resistance.

Ring and Disk Clutches: Many clutches of the friction type transmit motion from the driving to the driven side through the frictional resistance of rings, plates, or disks which are pressed together, the resistance being between the flat surfaces of the rings or disks which are thus held in contact. Some clutches of this general type have a few comparatively heavy rings, whereas others are equipped with a larger number of thin rings. By using quite a number of disks or rings instead of one or two, the diameter of the clutch may be reduced without sacrificing the contact area or the amount of frictional surface. Various combinations of materials are used for the disks of multiple-disk clutches. One set, for example, may be of soft steel and the other of phosphor-bronze, and in other types one set of disks is faced with some special friction material such as asbestos wire fabric, as in the case of dry plate clutches, the disks of which are not lubricated like those of a clutch having, for example, the steel and phosphor-bronze combination. See also Induction Clutch, Magnetic Clutch.

Clutches that Automatically Disengage. The clutches used on power presses and some other kinds of machines are designed to automatically disengage after making one or more revolutions. The clutch connects the fly-wheel or driving gear of the press with the driven shaft, whenever it is tripped, by pressing down a foot-treadle. As long as this treadle is held down, the clutch re-

mains in engagement and the press continues to run; if the treadle is released, the clutch is disengaged when the ram or slide of the press is approximately at the top of its stroke. The downward movement of the treadle releases a pin, key, or some other form of locking device which quickly engages the driving member; when the treadle is released, the locking device encounters some form of trip or cam surface which withdraws it and stops the press. There are many designs of clutches of this general type.

Coal. Coal, in the ordinary sense of the word, includes a number of carbonaceous materials used as fuel. The different kinds of coal all contain carbon, hydrogen, oxygen, and nitrogen, forming a carbonaceous or combustible portion, and also some matter which remains after the combustion in the form of ash. The amount of ash varies considerably in different kinds of coal. The nearest approach to pure carbon is furnished by anthracite coal which contains over 90 per cent of this constituent. Coals of this kind burn with a very small flame, producing intense local heat and no smoke. Bituminous coal contains from 50 to 85 per cent of carbon. Lignite or brown coals have a comparatively low percentage of carbon, usually not exceeding 50 per cent, while the oxygen and hygroscopic water is high.

The U. S. Geological Survey classifies coal as anthracite, semi-anthracite, semi-bituminous, bituminous, sub-bituminous, and lignite.

Anthracite contains over 90 and sometimes up to 97 per cent of carbon and has a heating value per pound of combustible of from 14,500 to 15,000 B.T.U. Anthracite is hard and shiny, is slow to ignite, and burns slowly.

Semi-anthracite coal is similar to anthracite. It contains from 85 to 90 per cent of carbon and has a heating value, per pound of combustible, of from 14,500 to 15,500 B.T.U. It is not as hard as regular anthracite, is less shiny, and burns more rapidly.

Semi-bituminous coal contains from 75 to 85 per cent of carbon and has a heating value of from 15,500 to 16,000 B.T.U., per pound of combustible. This coal is softer than the anthracites and has a tendency to produce more smoke, but on account of its high heating value it is one of the best coals to use for power plant purposes.

Bituminous coal, generally known as soft coal, contains from 50 to 75 per cent of carbon and a large percentage of volatile matter, varying from 25 to 50 per cent. The heating value per pound of combustible is from 13,500 to 15,500 B.T.U. Coal of this kind gives out large volumes of smoke, and requires special care in firing and furnaces constructed so as to prevent smoke as far as possible.

Lignite, also known as *brown coal,* contains less than 50 per cent of carbon and over 50 per cent of volatile matter, and has a heating power per pound of combustible of from 11,000 to 13,500 B.T.U. Two types of lignite are recognized: (1) *sub-bituminous* coal, also known as *lignite, black lignite, brown coal, lignitic coal,* etc.; this kind resembles bituminous coal, is black and shiny, but disintegrates more rapidly than bituminous coal when exposed to the air, and its heating value is not as high as that of bituminous coal; (2) *lignite,* also known as *brown lignite* or *brown coal,* is distinctly brown in color and has a woody structure. It carries from 30 to 40 per cent of moisture and has a lower heating value than any of the other coals. It is, in fact, intermediate between coal and peat, and is fragile, splitting into small pieces when exposed to the air.

Coal and Gas Fuel-Oil Equivalents. See Fuel-oil Coal and Gas Equivalents.

Coal Combustion. See Combustion of Coal.

Coal Dust as Fuel. The fact that dust will burn with great rapidity accounts for the attempts to make use of pulverized fuel, which may be burned without smoke and with high economy. This fuel, instead of being introduced into the firebox in the ordinary manner, is first reduced to a powder by pulverization, and, in place of the ordinary boiler firebox, a combustion chamber is used in the form of a closed furnace lined with firebrick. This furnace is provided with an air injector having a nozzle which throws a constant stream of powdered fuel into the chamber, spraying it throughout the whole space of the firebox. This powder may be ignited by first raising the lining of the firebox to a high temperature by an open fire. The combustion of the powdered fuel then continues in an intense and regular manner under the action of the air current which carries it into the combustion chamber. It is probably the most economical method of burning coal as far as fuel efficiency alone is concerned. It is the most expensive method in regard to the auxiliary equipment and labor required and the necessity of various features being carefully looked after. The coal must have about 30 per cent of volatile matter and be pulverized to a certain degree of fineness in order to ignite satisfactorily. It cannot be stored for more than about a day without danger of spontaneous combustion. This makes necessary an elaborate system of conveyors to carry the coal from the pulverizers to the furnaces. In general, this is an impracticable system for small installations, but may be sufficiently economical to be very desirable for large installations.

Coal Gas. See Gas Production.

Coal Storage. Soft coal should preferably be stored in pockets or bins of concrete or brick. If a roof is provided to keep out rain and snow, it should be of non-combustible construction. The space between the roof and the top of the coal should be properly ventilated to avoid danger of explosion of gases. A cone-shaped and elevated bin in which coal is fed in at the top and removed at the bottom is regarded as the ideal arrangement. Spontaneous combustion is more to be feared from recently mined coal than from that which has been out of the mine for some time. The following precautions, however, are necessary to avoid the danger of spontaneous combustion in *all* soft coal storage:

1. Coal should not be piled against mill buildings or around combustible building supports or close to a frame building.
2. Storing near external sources of heat should be avoided, even though such heat may be moderate.
3. Not more than 500 tons should be placed in a pile, and 25 feet of clear space should be kept between piles.
4. Piles should not be more than 10 or 12 feet deep, and no part of the pile more than 10 feet to an air-cooled surface.
5. Alternate wetting and drying should be avoided, and if coal is received wet, it should be placed around the edges of the pile where air can get to it freely and where other coal will not be piled over it.
6. Lump and fine coal should be mingled as much as possible to avoid lumps forming air passages which facilitate the spread of fire.
7. Air should not be admitted to the interior of the pile through interstices around piers, timbers, etc.
8. Pipes about 1 inch in diameter should be located vertically in piles, one to each 300 to 400 square feet of area (three or four pipes ordinarily will be satisfactory for a 500-ton pile). The lower ends of these pipes should be at varying distances from the bottom of the pile. A thermometer should be lowered into these pipes at weekly intervals to ascertain the temperatures existing inside the pile. Pipes should be capped and plugged when not in use in order to prevent admission of air to the bottom of the pile.

Coal Storage Under Water. According to investigations carried out by the Bureau of Mines, the expense of under-water storage equipment is not justified except as a preventive of fires from spontaneous combustion. In fact, the amount of deterioration of coal during storage has been commonly overestimated. While underwater storage of coal prevents deterioration of calorific value, in five years' storage in the open air Pittsburg coal deteriorated only about 1 per cent in one year, 2 per cent in two years, and from 2.5 to 3 per cent in five years. Pocahontas coal , semi-bituminous type—lost less than 1 per cent of its heating

value during two years of outdoor exposure. The Sheridan, Wyoming, sub-bituminous coal, known as "black lignite," lost 3 to 5.5 per cent of its heat value in two and three-fourths years of outdoor storage, the greater part of this loss being in the first nine months. The lumps became badly cracked so that they broke up on handling. By the use of bins with air-tight bottoms and sides and a protecting layer of fine slack, the loss in heat value in one year can be kept below 3 per cent and the physical deterioration will thus be largely prevented.

Coarse Metal. A mixture of copper and iron sulphide obtained in the smelting of copper ore in a blast or reverberatory furnace. It is also known as *matte*.

Coarse-Threading Attachments. See Thread-cutting Attachments for Large Leads.

Coatings for Laying Out Lines. Common chalk or a mixture of whiting and alcohol is often employed in laying out rough castings in order that the lay-out lines may be easily seen. The whiting is sometimes mixed with water, but alcohol is preferable because it will dry quicker and does not tend to rust the surface. This mixture may be applied with a brush. For many purposes the surface can be coated satisfactorily by simply rubbing dry chalk over it. However, as lines which are drawn on a chalked surface are quite easily obliterated, permanence is given them by marking their location with small centerpunch marks. When iron or steel surfaces have been machined, they can be coated by moistening the surface and rubbing it with a piece of copper sulphate or blue-stone. The following copper-sulphate solution gives even better results: To 4 ounces of distilled or rain water, add all the copper sulphate that the water will dissolve; then add ten drops of sulphuric acid. Test by applying to a piece of steel and, if necessary, add four or five additional drops of acid. The thin copper film which is deposited by this solution makes it possible to easily see fine lines because of the difference in color between the copper and the metal beneath. For this reason, the copper-sulphate solution is very often used, especially when fine lines are required. The surface to be coppered should be polished and free from grease. Apply the solution with clean waste, and, if a bright copper coating is not obtained, add a few more drops of the solution; then scour the surface with a fine emery cloth and apply immediately a small quantity of fresh solution.

Cobalt. Cobalt is one of the metallic elements; its chemical symbol is Co, and its atomic weight, 59. Its specific gravity varies from 8.52 to 8.95, according to its state of purity. The specific gravity of unannealed pure metal is 8.79 and of annealed pure metal, 8.81, whereas the commercial metal has a specific gravi

of about 8.65. Its melting point is 1490 degrees C. (2714 degrees F.). The electric conductivity (silver = 100) is about 17. It is very magnetic, and ranks next to iron as a magnetic metal. The mean specific heat between 15 and 100 degrees C. (59 and 212 degrees F.) is 0.105. The hardness of cast cobalt is considerably greater than that of iron and nickel. The tensile strength of pure cast cobalt is about 34,000 pounds per square inch. This strength is raised to 37,000 pounds per square inch by annealing, and may be increased to 100,000 pounds per square inch by rolling and drawing into wire. The elastic limit is fairly close to the breaking load, and is considerably greater, proportionately, than that of iron or nickel. The addition of carbon to cobalt increases its tensile strength. The compressive strength of pure cast cobalt is 120,000 pounds per square inch. The impurities of commercial cobalt (up to 0.3 per cent of carbon in addition to small percentages of nickel, iron, sulphur, and silicon) raise the compressive strength to 175,000 pounds per square inch. The elastic limit in compression is, however, not more than about 50,000 pounds per square inch.

Cobaltcrom Steel. A tungstenless alloy or high-speed steel is known as cobaltcrom steel because it contains cobalt and chromium in addition to carbon. A typical steel of this kind contains about 1.5 per cent carbon, 12.5 per cent chromium, and 3.5 per cent cobalt. This steel can be hardened at a temperature of about 1830 degrees F., which is considerably lower than that required for high-speed steels containing tungsten. This lower hardening temperature for cobaltcrom is considered an important advantage in heat-treating tools having fine edges, such as milling cutters, reamers, taps, etc. Cobaltcrom tools are held at a temperature of about 1830 degrees F. until thoroughly "soaked"; then the temperature is reduced about 50 degrees, the tools are withdrawn from the furnace and allowed to cool in the atmosphere until the red color disappears, when the tools are quenched in oil until cold. Tools subject to shocks, such as pneumatic rivet sets, shear blades, etc., should be heated slowly to 1650 degrees F., the temperature then being reduced to about 1610 degrees F. The tool is then removed and permitted to cool in the atmosphere. There is no appreciable scaling in the heat-treatment of cobaltcrom steel. This steel can be cast in molds for making milling cutters, reamers, etc., in order to avoid fluting operations and permit finishing the tools by grinding.

Coefficient. In general a coefficient is a number prefixed to some other quantity by which this quantity is multiplied. In algebraic expressions, it is the number written at the left of a symbol and serves as a multiplier. Hence, in the expression

"3a," the figure "3" is the coefficient. A coefficient may also be expressed, in algebra, by a letter.

Coefficient of Expansion. Coefficient of linear expansion is the amount of expansion per unit of length due to an increase in temperature of one degree. The coefficient of cubical expansion is the amount of expansion per unit of volume for an increase in temperature of one degree. See Expansion.

Coefficient of Friction. The coefficient of friction is the ratio between the resistance to motion of a body due to friction, and the perpendicular pressure between the sliding and fixed surfaces. See Friction.

Coiling Springs. See Spring Coiling.

Coining Pressures. Special embossing or coining presses are required for many embossing operations in the manufacture of medals, jewelry, coins, silverware, etc. For such work as embossing coins or medals, enormous pressures are required in order to make the metal flow into every minute impression in the coining punch and die. The following pressures are required for embossing United States currency: Silver dollar, 160 tons; gold eagle, 110 tons; silver half-dollar, 98 tons; gold half-eagle, 60 tons; silver quarter-dollar, 60 tons; nickel, or five-cent piece, 60 tons; copper cent, 40 tons; dime, 35 tons. It will be noted that the gold half-eagle, silver quarter, and five-cent piece require the same pressure, although the sizes and weights differ greatly, thus indicating the comparative coining properties of gold, silver, and nickel.

A sharp impression depends upon pressure but also to a very great extent upon die construction. Fifty tons can bring up a sharper, better looking job than five hundred if the dies are arranged to pinch just where the sharp lines are desired, and relieved elsewhere, so that the metal can flow.

Coining Process of Forging. See Forging by Coining Process.

Coke. Coke is a product obtained by heating coal in air-tight retorts to such a temperature that the volatile constituents are driven off; hence, coke consists mainly of carbon, together with the incombustible materials or ash contained in the coal, and also small amounts of oxygen, hydrogen, and nitrogen, generally not exceeding 2 or 3 per cent. Coke, when produced rapidly and at a low heat, as in gas making, is of a dull black color, igniting with comparative ease, but when produced by long-continued heat, as in making coke for iron and steel melting, it is hard and dense, has a brilliant luster and silver-gray color, and will only burn in furnaces provided with strong draft. This quality is brittle and

hard. One pound of coal will yield from 0.35 to 0.90 pound of dry coke, depending upon the kind of coal from which it is made. Coke is an important fuel in blast furnaces and foundries, but its cost is high, and for that reason it is not used for power plant purposes. Coke is classified either as foundry coke or furnace coke.

Foundry coke is a hard coke used in cupola furnaces for melting iron, and in large forge furnaces for heating iron and steel. It is dense, has a brilliant luster and silver-gray color, and will only burn in a furnace provided with strong draft. Generally, only coke that has been burned for seventy-two hours, while making, is classified as foundry coke.

Furnace coke is sometimes used in cupola furnaces, but is mainly employed for the melting of ore in blast furnaces. While being made it is burned for forty-eight hours. The standard quality should not contain more than 13 per cent of ash or 1 per cent of sulphur. When containing more than 1.2 per cent of sulphur, it is known as *smelter coke.*

Coke Breeze. Pulverized coke mainly used for covering the bottoms of soaking pits and crucible furnaces for protecting the brickwork. It is also known as *coke dust.*

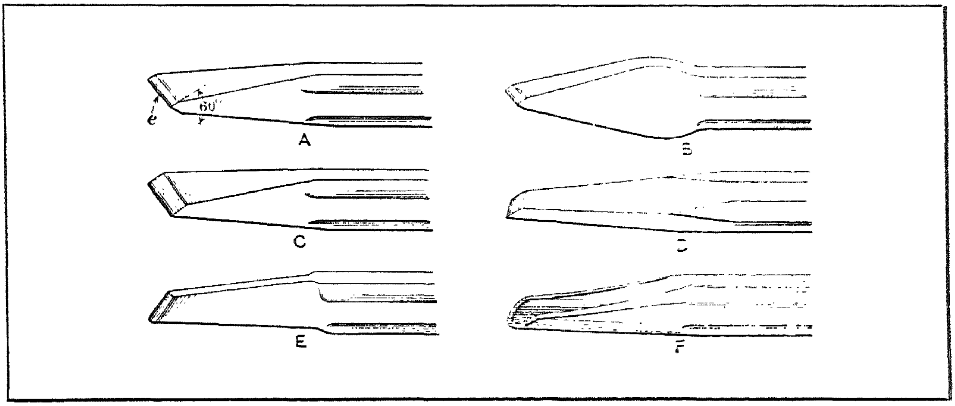
Coking Coal. Coke is the fuel commonly used in blast furnaces, and its purity, strength to resist crushing excessively under the blast furnace load, and porosity to permit free circulation of the gases, are important qualities which depend upon the kind of coal used in making the coke. The difference between coking and non-coking bituminous coals has been explained as follows: If the tars of the coal fuse and run at a temperature lower than that at which they volatilize or are driven off as a gas, then the coal may be said to be a coking coal. In this event, the freed tars permeating the fuel bed induce the formation of coke masses by closure of fuel particles and exclusion of air. Conversely, if the tars of the coal are of such composition that they volatilize and are driven off as a gas before they fuse and run through the fuel bed, the coal is then said to be a non-coking or a free-burning coal.

Colalloy. A metal of silvery appearance having only one-third the weight of steel. It has outstanding electrical and thermal conductivity, is unusually resistant to corrosion, and has great strength. It can be easily worked, formed, and shaped. Suitable for articles employed in the food industries, such as containers, pans, and trays. It is adapted for use in chemical and paint manufacturing plants, oil refineries, breweries, distilleries, rubber plants, paper mills, etc.

Colaweld. A liquid, paste, and rod for the atomic welding of metals without the use of welding apparatus. Not intended as a

substitute for welding by regular methods, but for cases heretofore difficult or impossible by ordinary welding methods. The paste and rod are intended for practically all non-ferrous materials, including aluminum; the liquid and rod for stainless and low-carbon steels and practically all ferrous alloys. Metal from 0.005 to 0.050 inch in thickness can be welded.

Colaweld Mormetal. A coating material that can be applied with a spray, brush, or as a powder and then heated by oven, torch, or other means to produce a fusion bond. High resistance to corrosion, abrasion, and erosion is provided. Zinc, cadmium, tin, bismuth, lead, and their alloys can be applied to ferrous and non-ferrous metals by this process. Useful for high-speed production in the fields of marine construction, transportation, building and general maintenance.



Different Types of Cold Chisels

Cold Chisels. The various types of "cold chisels" commonly used for chipping metals are shown in the illustration. The *flat chisel A* is used for a general class of work. The cutting edge *e* is either ground straight for light work or made slightly convex for heavy chipping to prevent the corners from breaking. The included angle at the end should be about 60 degrees, although a greater or less angle is advisable when the metal is either exceptionally hard or soft. A *cape chisel* is shown at *B*. This has a narrower cutting point than the flat chisel, and is used principally for cutting grooves, etc. The *side chisel C* differs from the flat type *A* in that it is ground and beveled on one side only, which permits it to be used on surfaces which could not be reached with a double-angle end; it is also used for chipping the sides of keyways, slots, etc. The *diamond point* shown at *D* is adapted to chipping V-grooves, squaring corners, etc., while the grooving

chisel *E* is for cutting oil grooves or for similar work. The *half-round chisel F* is known as a gouge, and, as its shape indicates, is used on curved surfaces.

Cold-Drawing. Cold-drawing, frequently, but erroneously referred to as cold-rolling, is a process to which round, square, or hexagonal bars may be subjected in order to improve the physical properties of the surface, to produce bars of accurate dimensions, and to obtain smooth, even surfaces. The process is briefly as follows: The ordinary hot-rolled bars are first pickled in order to remove the scale. They are then cold-drawn through dies and straightened.

Very little bar stock is cold-rolled today, and although the term "cold-rolled" is still generally used, nearly all the material known as "cold-rolled" is actually cold-drawn. A few manufacturers cold-roll bars over 4½ or 5 inches in diameter, but the general practice on large-diameter bars, especially shafting, is to turn and polish rather than to cold-roll. The largest tonnage of cold-rolled material is in strip stock.

Objects of Cold-finishing: The objects of both cold-drawing and cold-rolling may be one or more of the following: (1) To secure accuracy of size; (2) to obtain a smooth, even surface; (3) to produce thin, complicated sections; or (4) to affect the physical properties.

Dies for Cold-drawing: The dies are generally made of a special alloy tool steel that is very high in carbon, some analyses running as high as 2 per cent. Dies for rounds are solid; those for squares, hexagons, and flats are made up of sections, as are most dies for special sections. The Brinell hardness will run from 500 to 600, the harder die being desired for the smaller sizes. The life of a die averages about twenty-five coils on alloy-steel-wire sizes. On bars 20 to 30 feet in length, the average life will be about 500 bars.

Drawing the Steel: The drawing machines are horizontal benches, driven by individual motors. The grip or jaws, which take hold of the pointed end of the bar, engage with an endless chain which draws the material through the die. For wire sizes or coils, two types of drum machines are used. On one the axis of the drum is horizontal. This is used for the larger sizes of coiled stock—from about ½ inch to 1 inch; it is generally called a "bull block." The drums for drawing smaller sizes (from ⅜ inch down) have the axis of the drum vertical. These are the wire blocks. In wire mills, one operator may have charge of a number of drums, just as in a machine shop, one man may operate several automatic machines.

Reduction in Drawing: The draft or reduction per pass varies with the size, analysis, and finish desired. The usual practice is

to reduce the diameter 1/16 inch on sizes down to 5/16 inch. Under 5/16 inch, the reduction is generally 1/32 inch. This applies to such steels as screw stock, whether drawn in the hot-rolled, annealed, or heat-treated condition. In some cases, the reduction will be greater than 1/16 inch, and at other times less than 1/32 inch.

Finishing the Bars: After the material comes from the draw-bench, it must be straightened and cut to length. Straightening is most often done in a roll straightener, of which there are several types. In one type, the rolls that do the straightening revolve about the bar as it is fed through the machine. In another, the bar rotates as it moves between the rolls. The principle is that of deflecting the bar, first in one direction and then in the opposite direction, equal distances. The straightening also increases the smoothness of the bar; but if a high polish is desired, the bar will have to be passed through the machine several times.

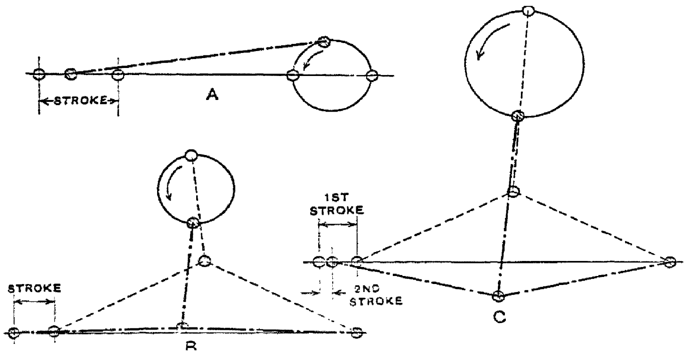
Effect on Physical Properties: The effect of cold-drawing upon the physical properties of carbon steel is to increase the elastic limit 60 to 100 per cent and the ultimate strength 20 to 40 per cent, and to decrease the elongation and reduction of area. The effect of cold-drawing upon hot-rolled alloy steel is not so marked, but it causes an appreciable increase in the elastic ratio. The difference is not so great when the bars are heat-treated. Generally, alloy steel heat-treated bars, after cold-drawing, will show an increase of 10 to 25 per cent in elastic limit and ultimate strength, and a decrease in the elongation and reduction of area.

Tolerances: The tolerances for cold-drawn shafting usually vary from 0.002 to 0.004 inch, the tolerance increasing with the size of the shafting. For shaft diameters less than 2½ or 2 inches, the tolerance according to common practice would be minus 0.002 or 0.0025 inch and the plus tolerance, zero. For larger shafts, the minus tolerance would be 0.001 or 0.0015 inch per inch of shaft diameter and the plus tolerance, zero.

Cold-Forging. The cold-forging process is applied in producing certain odd-shaped pieces that are squeezed to shape from solid metal in making parts for adding machines, sewing machines, speedometers, typewriters, electrical equipment, toys and novelties. On this class of work, the blank should be so designed that no more metal has to be squeezed down than is absolutely necessary. Note also that in the pieces which have a boss, hub, or other portion higher than the rest of the piece and left so by squeezing down the metal around it, there is a tendency in the process to drag down the corners and edges of such high parts. To minimize this tendency, it is often advisable to use a medium hard stock, and if necessary, arrange the dies so that

they will strike the high part at the end of the stroke and size it off. There may be considerable variation in the pressure required for this work on account of the area and thickness relation. For practical cases, however, with a free flow relief all around, 100 tons per square inch or higher on the area squeezed may be required for steel, and 75 tons per square inch for copper. See also Cold-pressed Forgings.

Cold-Headers. The design of cold-heading machines is based upon two distinct principles for reciprocating the movable ram of a cold-header: The crank principle, and the toggle principle. The crank principle is employed on most single-stroke machines and by at least one manufacturer for double-stroke machines as

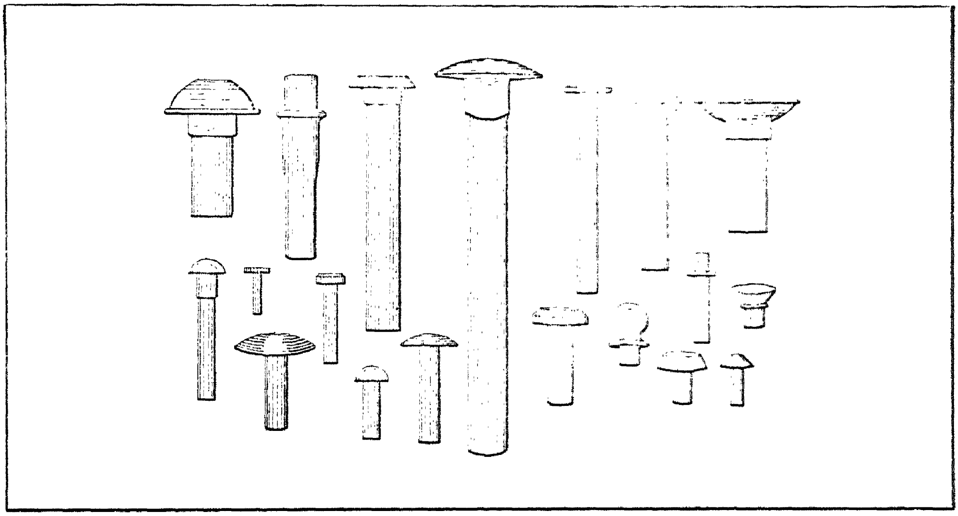


(A) Crank-header Diagram. (B) Two-cycle Toggle-header.
(C) One-cycle Toggle-header.

well. On double-stroke cold-headers of the crank-operated type (see illustration *A*), the crankshaft must make two revolutions in order to secure the two strokes, and these two strokes will be of equal length. The blow secured by the crank-operated header is of a quick punching character rather than a gradual squeezing operation, and exponents of crank-operated headers consider this feature to be of great importance.

The common type of toggle action is that shown at *B;* the toggle is straightened by a crank-actuated link which brings the arms of the toggle to a straight line once during each revolution of the crankshaft. This gives one stroke of the ram to each revolution of the crankshaft, but a gradual squeezing movement is obtained, especially at the ends of the stroke where the greatest amount of work is done. This type of toggle mechanism is known as the "two-cycle" type, two revolutions of the crankshaft

being necessary to complete a "two-blow" rivet. Another type of toggle-operating mechanism which is extensively used on the double-stroke machines is shown at *C;* as will be seen, two blows are struck at each revolution of the crankshaft which operates the arms of the toggle. As this type of machine makes a two-blow rivet in the revolution, it is termed a "one-cycle" machine. The chief difference between the two-cycle type of toggle and the one-cycle type lies in the fact that in the two-cycle mechanism the toggle is straightened when the extreme of the crank motion is reached, but in the one-cycle mechanism it is straightened and then pushed beyond the central position by the crank,



Miscellaneous Examples of Cold-heading

so that in the latter machine two blows are secured during one revolution of the crankshaft.

Many heading jobs require two distinct operations to perform the work, usually on account of the shape of the pieces. For this purpose, the work is carried as far as possible with an ordinary single- or double-stroke header, after which the pieces are annealed and completed in a reheader. For handling work in which the length of the pieces under the head exceeds nine or ten diameters of the wire, it is necessary to employ dies which open longitudinally to make ejection of the work possible.

Cold-Heading. The operation of forming the heads of rivets, wood-screw blanks, machine-screw blanks, and similar products, by upsetting the ends of the wire lengths while cold, is known as *cold-heading.* The machine to which the wire is fed from a coil, and in which it is cut off and headed, are known as

headers. A general idea of the classes of work done by cold-heading may be obtained from the illustration, which shows some miscellaneous examples.

In all cold-heading operations the blank is confined at the bottom and sides, leaving the metal which is to comprise the head projecting, so that it may be upset and shaped by the punch of the heading machine. In cold-heading, the fundamental point to be remembered is that, under pressure, the wire stock will always flow in the direction of the least resistance. Cold-heading by machinery was first introduced in England, about 1760, when two brothers, John and William Wyatt, designed and built a machine for heading wood-screw blanks. In America, Josiah Gilbert Pierson's cold-header, patented March 23, 1794, was the first machine of its kind, although the patents were destroyed when the patent office was burned early in the last century.

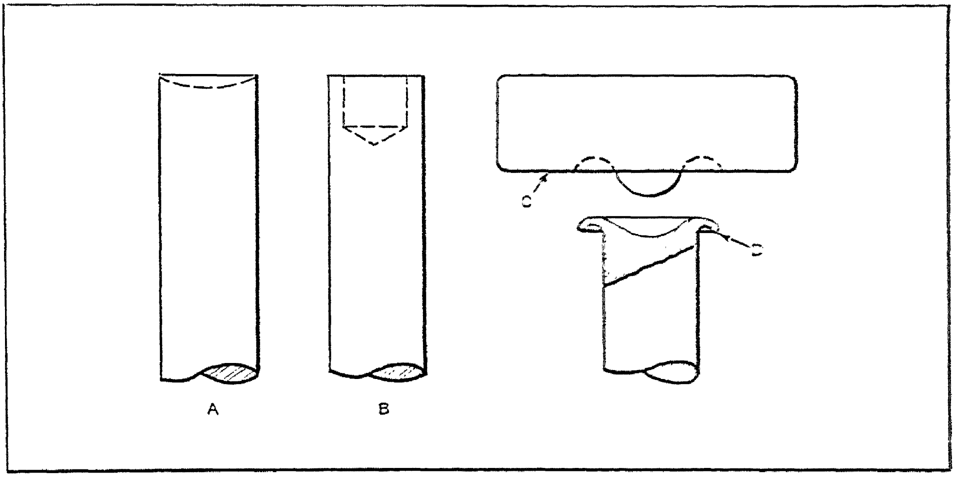
Cold-Pressed Castings. Castings of brass, bronze, aluminum and various alloys, as well as some steel and malleable castings, may be finished by a cold sizing or pressing operation in a powerful press equipped with dies shaped to suit the work. This general process may be for accurate sizing or it may be utilized in preparing some classes of hardware castings for plating, as the surface of a casting can be pressed smooth enough to eliminate or greatly reduce preparatory hand work and buffing. The pressure for such work is liable to be approximately 90 tons per square inch of projected area.

Cold-Pressed Forgings. The bosses and angular or flat surfaces, etc., on many of the smaller classes of drop forgings may be finished to size within a plus and minus tolerance of about 0.001 inch, by a cold-pressing or cold-sizing process. A powerful press such as the knuckle joint type, is used in conjunction with dies shaped to suit the shape of the boss or other part of the forging, and the working pressure may be as high as 100 tons per square inch or even higher. The object of this cold-finishing or squeezing method of sizing forgings is to obtain accuracy of form and size quickly and without milling or grinding operations.

The usual finish allowance for work of this character is 1/32 inch and in some cases 1/16 inch. More can be allowed, but is not required. It may be pointed out that if the rough forgings vary considerably, the pressure which the press is required to exert will also vary considerably. Accordingly, if the press is not heavy and of rigid construction, it will spring in proportion to the load, giving a possible variation beyond the tolerance. It is best to figure the pressure requirement for sizing

work (close tolerance, small compression, free flow) at about 60 to 80 tons per square inch of surface to be squeezed; 400-, 600-, and 800-ton capacity presses seem to have proved the most satisfactory for the general run of automobile forgings.

Cold Rivets. In the manufacture of some products, it is the practice to use "cold rivets" which, instead of having heads, are cupped out on the ends to permit upsetting sufficiently to form a small flange or head. One type of cold rivet is shown at *A* in the accompanying illustration. These rivets are made slightly concave at each end so that they may be readily headed by a pneumatic hammer. At *B* is shown a rivet with a drilled hole at each end. The holes are drilled about 1/4 inch deep and of



Cold Rivet Head Formation

such diameter as to leave a wall from 1/16 to 5/32 inch thick, depending on the size of the rivet. Rivets of this design can readily be upset on both ends at one operation in a hydraulic press by equipping the upper and lower dies with hardened steel buttons like that shown at *C*. The shape of the head after compressing is shown at *D*.

Cold-Rolled Sheet Steel. Cold-rolled steel possesses several advantages which cannot be secured with metal that is rolled hot. Most important of these is that rolling the metal cold enables it to be given a so-called "bright" finish, there being no oxide scale or stains on the surface. When the steel is rolled hot, the hot metal is easily attacked by the oxygen of the air, which results in forming the scale with which heated metal is covered. This oxide scale is hard and it exerts a very harmful effect on the dies used for working sheet metals. For this

reason, cold-rolled steel is extensively used in the manufacture of various pressed steel products. The possibility of rolling steel without forming any scale has another important advantage, in that sheet metal produced in this way can be rolled very thin, the limit being about 0.003 inch; evidently this would be impossible if the metal were at a red heat, because the production of scale would cause considerable variation in the gage of the metal, and would destroy very thin sheets.

Mills engaged in the manufacture of cold-rolled steel secure their raw material in the form of ribbon stock which is considerably thicker than the cold-rolled steel to be produced. The treatment of this material in the early stages of the process differs according to the carbon content. For steel which does not contain over 0.30 per cent of carbon, it is unnecessary to conduct a preliminary annealing process, but steel with more than 0.30 per cent of carbon must be annealed before rolling. The amount of reduction which can be obtained for each pass through the rolling mills depends upon the analysis of the steel; with low-carbon steel, the reduction may be as great as 0.022 inch for each pass, and this reduction will be gradually reduced until the final pass will only reduce the thickness of the metal about 0.005 inch. In the case of high-carbon stock, the reduction at each pass through the mill is much less.

Cold-Rolling. The cold-rolling of shafting or bar stock consists in passing the shaft or bar through burnishing rolls which leave a smooth dense surface. Most shafts and bars, however, which are designated as "cold-rolled," have been finished by a cold-drawing process which involves pulling the stock through dies. See Cold-drawing.

Cold-saw Cutting-off Machines. Cold-saw machines which utilize a revolving saw are built in many different designs which differ principally in regard to the methods of driving the saw and giving it a feeding movement relative to the work. The saw is usually mounted on an arbor, which is rotated either through spur gearing, worm gearing, a combination of spur and worm gearing, or by the direct action of a sprocket engaging either the saw teeth or radial slots formed in the saw. A general method of feeding the saw is by means of a carriage or saddle which carries the saw and its driving mechanism, and is moved along the bed by a feed-screw. Some machines are so arranged that the saw is given a swinging movement for feeding it, by mounting the saw upon an arm which is pivoted and connected with suitable feeding mechanism, which may be in the form of worm gearing, a pinion meshing with a segment gear on the arm, or a gear-driven screw connected with the arm.

Duplex Cold Saw: The Duplex type of cold saw consists of two machines mounted upon the same bed so that the distance between the saws may be varied. Machines of this type are used for cutting off the ends of axles, crankshafts, etc., to given lengths, and also for sawing crankshafts in order to form the crank or web from a solid forging.

Multiple Cold Saw: The multiple cold saw cutting-off machine is used for cutting long bars into a number of short lengths. One machine of this type is equipped with six heads each having a saw which operates independently. The saws feed forward and return automatically. These machines are usually designed and built to suit special classes of work.

Cold Saw of Vertical Type: Some cutting-off machines have a vertical spindle and a saw which revolves in a horizontal plane. One design which is especially adapted for cutting off gates and risers from cast-steel gears, and other similar work, has a circular work table which is arranged very much like the table of an ordinary slotting machine. Another type of cold saw which is designed along vertical lines has a vertical column on the face of which is a saddle carrying a horizontal saw arbor, the saw in this case being in a vertical plane. The vertical column may be fed horizontally along the main base of the machine and the saddle may also be given a vertical feeding movement on the face of the column. A machine of this type is especially adapted for sawing armor plate.

Cold Shuts. A cold shut is caused by the imperfect uniting of two or more streams of molten iron flowing together, which are too cold to coalesce. Such a fault often occurs on the upper side of a thin cylinder cast horizontally, when the iron is not sufficiently hot at the instant of pouring. It appears as a seam in the side of the cylinder, and it is very apparent that the metal has united imperfectly. Such a defect will cause the casting to split if subjected to any great stress, and it will leak under pressure. This imperfection is generaly due to thinness of the metal or to improper gating. If the iron flows in thin streams for comparatively long distances, it will be cooled very much, and probably the advancing face will be partially solidified.

Cold Test of Oil. The cold test of an oil is to determine the lowest temperature at which the oil will pour. A low cold test is desirable in cold weather to insure proper circulation and handling; furthermore, a low cold test for motor oils indicates the absence of heavy elements that produce carbon in the cylinders. The effect of decrease in temperature upon lubricating oils is not the same as on fluids such as water, glycerin, etc., which have fixed freezing points. Lubricating oils, which contain

elements having different melting points, often deposit some of these elements before the entire mixture solidifies; consequently, the "cold test" or setting point of an oil may represent the temperature at which the solid matter begins to separate, or it may be the temperature at which the oil loses its fluidity. The setting point of a Scotch mineral oil is the temperature at which the solid paraffin begins to separate. Some pale American oils of high viscosity, Russian oils, and all dark opaque oils, which either deposit no paraffin or in which the separation cannot be seen, are considered to have reached the setting point when they cease to flow.

Cold-Twisting. Cold-twisting is the term applied to a process for producing bars for reinforced concrete construction. The cold-twisting increases the elastic limit and produces a bar which has a more intimate bond with the concrete and greater reinforcing effect.

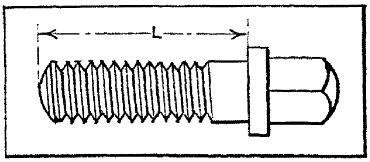
Coleco Metal. The bearing metal known as *coleco metal* is a lead-tin-antimony alloy, also containing a small percentage of copper. One composition specifies 77 per cent of lead, 14 per cent of antimony, 8 per cent of tin, and 1 per cent of copper.

Collapsible Taps. See Taps, Collapsible.

Collapsible Tubes. Collapsible tubes, such as are commonly used for artists' colors, tooth paste, etc., are usually manufactured by the cold extrusion process. The metal from which these tubes are made is of either tin or lead composition and there is a large variety of alloys suitable for this class of work. These tubes are also often made from pure tin, and such tubes are considered superior to those made from the various compositions. The tubes are extruded from blanks of disk or special shapes.

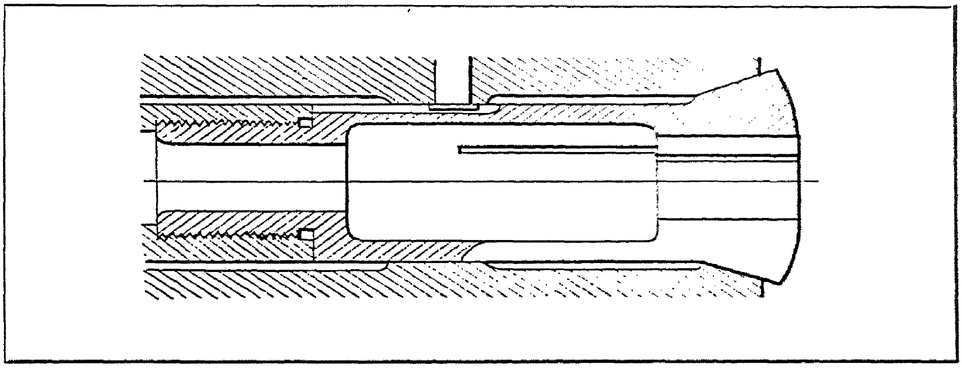
An alloy which will be found suitable for both collapsible tubes and soft metal bottle tops, consists of 4 ounces copper, 6 ounces antimony and 16 ounces tin, melted together, the resulting alloy being used with varying quantities of pig tin. For collapsible tubes 50 ounces of the alloy and 200 pounds of pig tin are used; for bottle tops, 134 ounces of the alloy and 200 pounds of pig tin. Any one of the three following compositions may also be used successfully in the manufacture of collapsible tubes: (1) antimony 14 per cent and tin 86 per cent; (2) antimony 5 per cent and tin 95 per cent; (3) copper 2 per cent and tin 98 per cent. Collapsible tubes are now being produced successfully from aluminum. The annealing process for restoring the ductility of the metal after extrusion is an important part of this development.

Collar-Head Screws. Collar-head screws are used on finished work, or on rough work which has been spot-faced to provide a bearing for the collar or enlarged part of the head. Screws of the collar-head form are also commonly used in toolposts or tool-holders of various kinds; the particular advantage is that the collar prevents a wrench from slipping down below the head, thus causing inconvenience in making adjustments. Dimension *L* (see illustration) represents the nominal length of the screw.



Collar-head Screw

Collet Chuck. The collet type of chuck consists of a split sleeve or collet which has a tapering or conical end that fits into a seat of corresponding taper so that a lengthwise movement of the collet causes a contraction or expansion of the gripping surfaces (see illustration). The collet type of chuck is the most convenient form for gripping pieces that are long in relation to their diameter, such as bar stock, etc. Collet chucks are extensively used on bench lathes, turret lathes (when operating on bar stock), and on turning machines of the automatic screw machine class.


Collet Chuck

Some collet chucks are closed by a backward pull and others by a forward push, the movement for closing depending upon the inclination of the taper.

Colloidal Fuel. A mixture of fuel oil and pure coal is known as colloidal fuel. The usual amount of coal is about 40 per cent by weight, with possibly 1 per cent of some emulsifying agent. The oil may have suspended in it, however, as much as 65 per cent of coal by weight and yet be sufficiently fluid to permit

pumping or atomization. The object is to combine with the oil low-grade coals of the high fixed carbon or high ash types which cannot be burned successfully in the usual manner. Colloidal fuel has a heating value per pound varying from 14,500 to 17,000 British thermal units, a weight of 8.3 to 11 pounds per gallon, and for equal volumes it has nearly twice the power value of coal, and nearly 10 per cent more than fuel oil. It can be covered with water and sinks in water, thus reducing the fire hazard.

Cologarithms. The cologarithm of a number is the logarithm of the reciprocal of that number. "Cologs" have no properties different from those of ordinary logarithms but they enable division to be carried out by addition because the addition of a colog is the same as the subtraction of a logarithm.

Coloring Metals. See kind of metal or finish: Brass Coloring; Copper Coloring; Cyanide Coloring of Steel; Flemish Finish on Brass; Heat-black Finish; Silver Finish on Brass; Steel Coloring.

Coloring Polished Parts. The term "coloring," as used in the metal finishing trade in connection with polishing or buffing, refers to the operation whereby a very fine finish is obtained. Chisels, hammers, screwdrivers, wrenches, and similar classes of work which are to be highly finished, but not plated, usually require four operations which are: roughing, dry-fining, greasing and coloring. That is, by means of four operations all the finishing work is done on polishing wheels, including the roughing which is frequently regarded as a solid grinding wheel job. Sometimes there are two steps to the greasing operation—rough and fine greasing. For some hardware, typical of which are cheaper screwdrivers and wrenches that do not demand a high finish, two operations are sufficient—roughing and dry-fining. The coloring operation may follow plating in order to give the plated surfaces a luster.

Columbium. A metallic element of steel gray color and having a bright metallic luster, also known as *niobium.* Its chemical symbol is either Cb or Nb; atomic weight, 93.5; specific gravity about 7; and melting point 2200 degrees C. (about 4000 degrees F.). Iron containing 3 per cent columbium has been found to have exceptionally good rupture strength at temperatures as high as 1100 degrees F., indicating potential applications in high-temperature steam turbine construction. By itself the element is malleable and ductile, and highly resistant to corrosion. At one time it was used in lamp filaments, and is now used in jewelry. There is also a columbium-stabilized 18-8 (stainless)

steel in which the columbium forms a carbide. The element does not occur in the free state, and its minerals are relatively rare. Only a small tonnage is produced annually and this comes chiefly from Australia. The element was discovered in 1801 in America and hence was named columbium.

Column. In engineering, a column is a structural member which has considerable length in proportion to its width, depth, or diameter, so that failure in compression is most likely to occur by the effect of bending stresses rather than by crushing. Generally, a structural member subjected to compression is known as a column, strut, or post if its length exceeds from six to ten times its width, depth, or diameter.

Column Formulas. See Rankine's Formulas.

Combination Chucks. The combination type of chuck is so arranged that the jaws may be adjusted either independently or universally. There are two common methods of obtaining this change of adjustment. In the design having geared screws operated by a circular rack or gear, the latter is so arranged that it may be dropped out of mesh with the screw pinions, so that each screw may be turned independently. With a scroll type of combination chuck, all of the jaws may be moved together by rotating a spiral scroll or they may be adjusted independently by turning screws that are located between the jaws and the scroll.

Combination Grinding Wheel. When a wheel is made up of abrasive grains of different sizes or numbers, it is known as a combination wheel. The coarser grains are effective in taking roughing cuts, but the wheel is sufficiently compact to obtain a fine finish if properly used. Such wheels are extensively employed.

Combined Carbon. This is the form in which carbon is present in white cast iron, the carbon being in chemical combination with iron as cementite or carbide of iron, (Fe_3C). The combined carbon is the principal factor in determining the hardness, strength, and soundness of castings.

Combustion. Chemically considered, combustion is the chemical union of oxygen with other elements and compounds at a rapid rate — usually so rapid that heat and flame are produced. When combustion is extremely rapid, it is termed an "explosion."

The combustion of a fuel requires three stages: 1. The absorption of heat to raise its temperature to the point of ignition. 2. The distillation and burning of the volatile gases. 3. The combustion of the fixed carbon. When fresh fuel is added to the fire, it absorbs heat until its temperature reaches the point

at which the combustible elements will unite with the oxygen of the air. This point varies with the kind of fuel, commonly running from 600 to 800 degrees F. in the case of lump coal and coke. Carbon monoxide requires a temperature of 1210 degrees F., and hydrogen, 1100 degrees F. While the coal is being raised to the point of ignition, the so-called "hydrocarbons," such as marsh gas, tar, pitch, naphtha, etc., are driven off in the form of a gas and combine with the oxygen of the air which is supplied through the bed of the hot fuel. When the hydrocarbons have been driven off, combustion of the solid portion of the fuel, that is, the carbon, takes place. This unites with the oxygen of the air to form carbon monoxide and carbon dioxide. Any substances which are not combustible remain in the form of ash and clinker.

Air Required for Combustion: The theoretical amount of air required for the combustion of various fuels, in pounds per pound of fuel, based on typical analyses of each is as follows: Coke, 10.8; anthracite, 11.7; bituminous coal, 11.6; lignite, 8.9; wood, 6.0; and oil, 14.3. In practice, due to the impurities in fuel and the difficulty in getting air into contact with all particles, it is impossible to obtain perfect combustion with the theoretical amount of air, and an excess sometimes equal to double the theoretical amount is required. Usually, however, about 50 per cent excess air is sufficient to meet the requirements. This excess air is required because ideal conditions for combustion cannot be attained in actual practice, owing to the difficulty in supplying air to all parts of the fire uniformly. This results in some of the fuel receiving less oxygen than is necessary for complete combustion, while other parts have a surplus. On the other hand, if too much air is supplied and insufficient time is allowed after the gases have become incandescent, before they come in contact with the cooler plates of the boiler, combustion will also be retarded.

Combustion Elements in Fuels. The elements contained in the usual forms of fuel, which enter into the process of combustion, are oxygen, carbon, hydrogen, and sulphur. There are various other constituents present which have no fuel value, such as the iron, silicon, etc., found in coal. These usually exist in small quantities, and are classed as impurities. They produce a certain waste in the form of ash, and, in addition to this, their temperature must be raised to that of the fire before becoming separated from the other elements, and more or less of this heat is lost as they are discharged from the fire.

Oxygen is the universal element of combustion; it is an invisible gas and makes up about one-fifth the volume of the air

in an uncombined state. It is usually present in coal in amounts varying from 1 to 25 per cent, according to the grade. *Carbon* is a solid, and is found in a pure state in the form of graphite and charcoal. It is the principal heat-producing element in coal and other fuels, including liquids and gases. *Hydrogen* is a combustible gas, and exists in nature only in combination with some other element.

Nitrogen is an invisible gas, forming about four-fifths the volume of the atmosphere. It does not unite chemically with the other constituents of the air or take any part in the process of combustion. For this reason it is a source of loss in the operation of a steam boiler, because, in order to supply the necessary oxygen for combustion, four times the volume of nitrogen must be raised from the temperature of the atmosphere to the point of combustion, and then discharged at a high temperature with the waste gases into the chimney. This process adds nothing to the heat of the furnace and is constantly extracting heat from it. Nitrogen is found in coal in amounts varying from 0.5 to 2 per cent, by weight. *Sulphur* enters into the composition of coal in amounts varying from 0.5 to 5 per cent. Although sulphur is combustible, the amount of heat given off is small, and the gases are so detrimental to the boiler plates that it is commonly considered an impurity.

Combustion of Coal. Combustion of coal involves the rapid chemical union of oxygen with carbon, hydrogen, and sulphur (and other elements) accompanied by a diffusion of heat and light. Perfect combustion occurs when the combustible unites with the greatest possible amount of oxygen, but without excess. Imperfect combustion occurs when the union between the combustible and oxygen is incomplete, or when an excess of oxygen is present. The principal combustibles in fuels are carbon, hydrogen, and sulphur. Carbon is the most abundant. Hydrogen is usually found in combination with carbon in the form of hydrocarbons. Sulphur is found in most coals. It usually occurs either as a sulphite of iron or a sulphate of lime.

Each combustible element will unite with oxygen in certain definite proportions and will generate a definite amount of heat which is termed the *calorific value* of the substance. Some calorific values of elementary combustion are given below. Carbon to carbon dioxide, 14,600 B.T.U.; carbon to carbon monoxide, 4450 B.T.U.; carbon monoxide to carbon dioxide, 10,150 B.T.U.; hydrogen to water, 62,000 B.T.U.; methane CH_4 to carbon dioxide and water, 23,550 B.T.U.; sulphur to sulphur dioxide, 4050 B.T.U. Thus, when one pound of carbon is burned to carbon dioxide, sufficient heat is generated to raise 14,600 pounds of

water one degree, or one-half of this amount of water two degrees.

Combustion, Spontaneous. See Spontaneous Combustion.

Combustion, Surface. See Surface Combustion.

Commutating Poles. Small narrow poles placed between the main poles of direct-current machines for preventing sparking between one of the edges of the brushes and the commutator. The commutating poles are wound in series with the armature winding and this exciting winding carries a current proportional to the load current and produces a flux in such a direction and phase as to assist the reversal of the current in the short circuited coil.

Commutation. The currents flowing in the armature coils of a direct current generator are reversed in direction as each coil segment passes from the field of one magnetic pole into the field of one of the opposite polarity. A direct current can, however, be made to flow through the generator terminals if provision is made for reversing the connections from each coil to the external circuit as the direction of the electromotive force induced in the coil reverses. This is accomplished by the proper spacing of armature coils and their connections to the individual segments of the commutator so that contact with the brushes is made at the proper moment with respect to the position of the coils in the magnetic pole fields. When the connections to an armature coil are so reversed, the coil is said to undergo *commutation.*

In the case of a direct current motor, since direct current is supplied to its terminals, commutation is provided to change the direction of current flowing in each coil as it passes from one magnetic field to another of the opposite polarity so that continuous torque in the same direction may be applied to the armature.

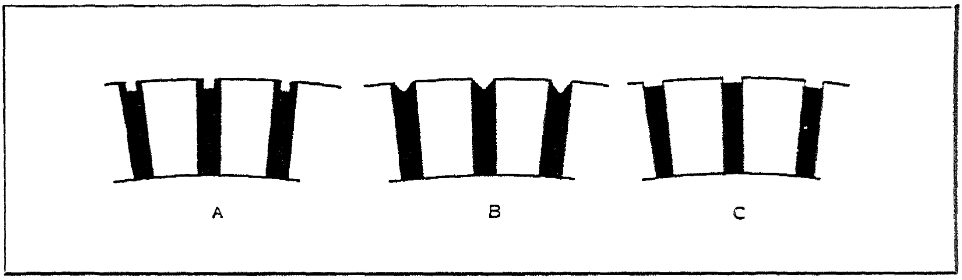
Commutator. See Armature, Motor; also Generators, Direct-current.

Commutator Controller. A hand-operated electric motor controller of the non-automatic type used as a reversing controller. It is similar in construction to the drum controller, except that in the commutator controller the fingers revolve instead of the drum. This controller is limited in size to approximately from 100 to 150 horsepower, but is mechanically strong and simple to operate and can be provided with brushes that make it very durable in heavy service. See also Drum Controller.

Commutator Insulation. The mica insulation between the copper commutator segments is usually more resistant to the

wear of the brushes than the segments. This results in the copper wearing off and leaving the mica projecting, a condition termed "high mica." Pure amber mica, which has about the same wearing qualities as the copper used in commutator segments, was formerly used, but it is very expensive and difficult to obtain. The mica used consists of built-up sheets made from plates or lamellae 0.002 to 0.004 inch thick of both amber mica and the harder, white kind of mica stuck together with some gum or resin. Both the white mica and the baked binder are harder and more resistant to wear than the copper commutator segments.

In order to prevent the "high mica" condition, the mica is generally grooved or under-cut between the segments as shown at *A*, and *B*. The style of under-cut as shown at *A* has been considered the better, although its superiority, if any, is not pronounced. The condition shown at *C* should be avoided, espe-



Commutator Mica Insulation

cially in the case of large, slow-speed machines, or machines operating in places where dust of a current-conducting nature is prevalent. The entire brush contact area should be grooved without having the grooves run out on the end of the commutator. Ordinarily, the grooves should be about 1/32 inch deep.

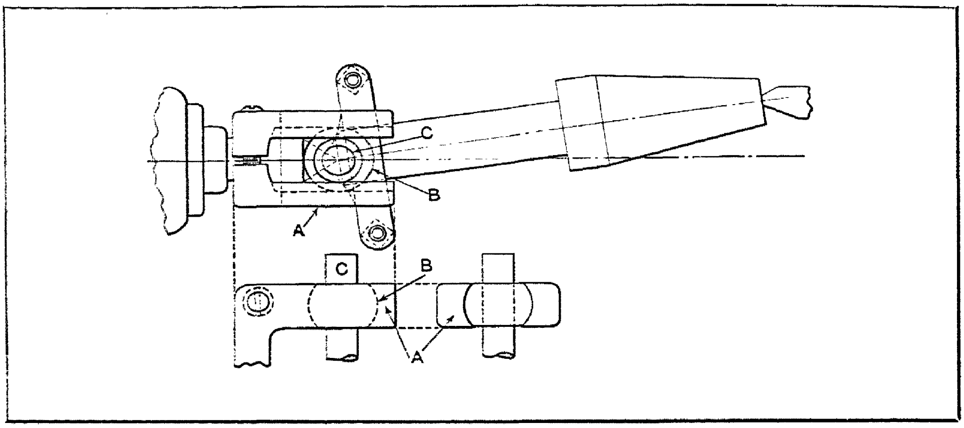
Commutator Motors, Alternating Current. There are two main types of alternating-current motors with commutator-connected windings: series motors and repulsion motors.

Alternating-current series motors are much like direct-current series motors in their characteristics. Their construction is different, however, in that they have laminated field structures instead of a cast structure to prevent excess eddy-currents and only a few turns in the field coils to avoid low power factor from high inductance. They are widely used in low power applications requiring motors of from 1/100 to 1/3 horsepower, and in these sizes are often termed *universal* as they may also

be operated on direct current. They are called series motors because the stator and rotor windings are connected in series.

Repulsion motors are equipped with a commutator-connected winding which provides a high starting torque. In the *repulsion-start induction* motor, this winding is cut out, after the machine reaches a certain per cent of synchronous speed, by the short-circuiting or lifting of the brushes from the commutator. The motor then runs as a straight induction motor on a squirrel-cage winding.

In the *repulsion induction motor,* the brushes are not disconnected and part of the current merely shifts from the repulsion winding to the squirrel-cage winding as the motor comes up to speed.



Compensating Dog to Eliminate Indexing Errors

Also using a commutator, is a polyphase adjustable-speed motor which has two sets of brushes that are shifted for speed control.

Compensating Dog. A compensating dog or driver is a type designed to prevent the inaccuracy in spacing which often results when indexing taper work. If the axis of the work is not in alignment with the axis of the dividing-head spindle, and an ordinary driver is used, the spaces will vary somewhat, especially if the work is held at a considerable angle. A form of compensating driver which practically eliminates this error has a forked arm *A* (see illustration) which is secured to the dividing-head spindle. This arm is engaged by a ball-shaped part *B* mounted on the cylindrical end *C* of the driver. The latter is clamped in such a position that the center of the cylindrical driving end is approximately in line with the end of the work,

as shown by the plan view. The ball fits closely between the curved surfaces of the forked arm and adjusts itself as the relation between the driver and arm change owing to the angularity between the axes of the work and the index spindle. The forked arm can be adjusted to take up all play between the ball and the curved surfaces between which the ball is held. As the driving is done at a point opposite the end of the work, the irregularity of the indexing movement is very slight and negligible for ordinary milling or fluting operations; moreover, there is no binding action between the dog and driver plate, such as may occur with the ordinary dog, having a tapering driving end.

Compensators. Compensators for line drop are devices used to modify the reading of electric power station voltmeters, without the use of pressure wire from the distributing point, so that the reading corresponds to the pressure at that point. *Balances* are sometimes called compensators or direct-current compensators.

Complement of Angle. The complement of a given angle (a) equals $90° - a$; hence if the angle a exceeds 90 degrees, its complement is negative. The complement angle of a 60-degree angle equals $90 - 60 = 30$ degrees.

Composite Gear Tooth System. See Gear Tooth Standard, American.

Composition of Forces. The expression "composition of forces" relates to the finding of the resultant of two or more forces. See Force.

Compound. In chemistry, a compound is a substance consisting of chemically united atoms of two or more elements. For example, sulphuric acid which consists of hydrogen, sulphur, and oxygen is a chemical compound. Substances which can be decomposed into simpler ones are known as compounds; those which cannot be decomposed into anything simpler are known as *elements*.

A substance is a mechanical mixture or a chemical compound, according as the elements composing it lose or retain their identity. If chlorine and hydrogen are mixed in any proportion, the chlorine in the mixture may be evident by its characteristic color and odor, showing that the combination is only a mechanical mixture. If, however, this mixture is exposed to a strong light, a new compound is formed in which the chlorine cannot be detected either by any odor or color, nor can it be separated except by chemical means; this combination, known as hydrochloric acid, is a chemical compound. The gases, however, will combine only in exactly equal volumes, so that if there

is any excess of either element present that part will remain uncombined. This fact is true in all cases, as a chemical compound differs from a mechanical mixture in that each element of the chemical compound has a certain fixed and unvariable combining proportion, which is its valence; whereas, a mechanical mixture of substances can be made with varying amounts of each ingredient. In a mechanical mixture, the particles of each ingredient can usually be identified and separated by mechanical means, but, in a chemical combination, each component is so blended that its identity is lost.

Compound Dies. Compound dies differ from plain blanking and follow dies in that the simple punch and die elements are not separated but are combined so that both the upper and lower members contain what corresponds to a punch and die, as well as suitable stripper plates or ejectors. The faces of the punches, dies, and stripper plates are normally held at about the same level and the strippers are spring supported so as to recede when the stock is being cut. A compound die produces more accurate work than the types previously referred to for the reason that all operations are carried out simultaneously at one stroke, while the stock is firmly held between the spring-supported stripper plates and opposing die-faces. Such delicate parts as armed wheels or gear punchings for clocks, meters, etc., are examples of the work that can be done in this form of die. Such parts are made complete, including the arm spaces, center-hole, and holes in the arms or rim, if desired, during one stroke of the press.

Compound Indexing. See Indexing.

Compound Levers. It is sometimes necessary to use two or more levers connected one to the other in a series, where it would not be convenient to obtain the desired multiplication with a single lever, or where it is necessary to distribute the forces acting. In such cases, the levers are called *compound* levers, and their application is found in testing machines, car brakes, printing presses, and especially in weighing scales.

Compound Rest. The compound rest of a lathe consists of an upper slide mounted on the lower or main cross-slide. The upper slide can be turned to any angular position so that the tool, which ordinarily is moved either lengthwise or crosswise of the bed, can be moved at an angle. The base of the compound rest is graduated in degrees and the position of these graduations shows to what angle the upper slide is set. It is also known as a Compound Slide.

Compound Stresses. Stresses acting in two or three directions at the same time are called "compound stresses." An ex-

ample is found in a long thin cylinder closed at each end and subjected to internal fluid pressure. There is a tangential stress which tends to burst the cylinder along a line parallel with the axis, as well as a longitudinal stress, due to pressure on the heads, which tends to tear the cylinder apart in a plane perpendicular to the axis; that is, a small square in the wall of the cylinder is subjected to stress in two directions, each at right angles to the other. Similar examples are found in stresses due to combined bending and twisting in a shaft, stresses due to centrifugal force in a rotating wheel disk, and stresses in a hub pressed on a shaft. See Guest's Formula.

Compound Tolerances. A compound tolerance refers to those conditions where the established tolerances on more than one dimension determine the required limits. These exist in conjunction with the dimensioning of composite surfaces or those surfaces which are required to maintain a co-relation which cannot be expressed by a single dimension.

Compound-Wound Generator. This is a type of direct-current generator which is provided with both a series and a shunt field (see diagram) in order to keep the voltage constant as the load increases. The series winding automatically increases the excitation, and thus the voltage, as the load comes on, so as to counterbalance the drop in voltage that would take place, if only a shunt winding were provided. The series coils, therefore, reinforce the shunt field in direct proportion to the increase of load and thus hold the terminal voltage constant, balancing the drop due to increased copper loss and armature reaction at the increased load. To obtain a perfect regulation, it is also customary to provide an adjustable resistance in the shunt-field circuit similar to the simple shunt-wound generator. Compound-wound generators may be so proportioned that the voltage may be held constant over a wide range in load, and are then said to be "flat-compounded." They may also be so proportioned that the series field adds enough excitation not only to maintain a constant terminal voltage, but to increase the same as the load increases, and thus compensate for the voltage drop in the supply circuit and maintain an approximately constant voltage at the point of utilization. When so designed, the generator is said to be "over-compounded."

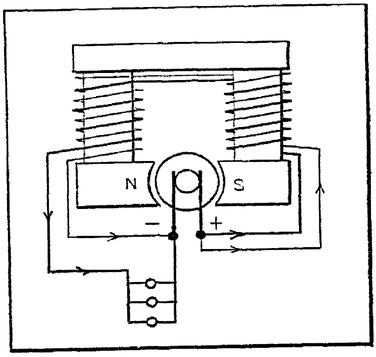


Diagram of Compound-wound Generator

Compound-Wound Motor. The compound-wound motor is a direct-current motor having both a shunt and a series field winding. The shunt field is connected to the main line as in a shunt motor, while the series field is in series with the armature and carries all of the current passing through it as in the series motor. The field of an average compound motor is composed of about eighty per cent of shunt winding and twenty per cent of series winding, although this proportion may be varied to suit the class of work for which the motor is to be used. The speed of a compound motor is more nearly constant than that of a series motor, but the drop in speed from no load to full load is considerably more than in a shunt motor, owing to the action of the series part of the winding. The characteristics of the compound motor partake of those of both the series and the shunt motors in about the same degree as the relative proportion of the two windings composing the field. See Series Wound Motor and Shunt Wound Motor.

Compressed Air Intercoolers. See Intercoolers for Compressed Air.

Compressed Air, Moisture in. The atmosphere contains a certain amount of moisture or water vapor, and its capacity for moisture increases with the temperature. When compressed, this water vapor is carried with the air through the pipes to places where the air is to be used, and, as the air is often cooled considerably during its passage through long pipe lines, the water vapor has a tendency to condense. This water due to condensation frequently causes trouble. Moisture or water cannot be entirely eliminated from service lines, but much of it may be deposited by proper cooling devices. Moisture enters the compressor in the free air and passes into the intercooler, where some of it is deposited by the sudden temperature drop there. In some machines, this deposited water is drained off, but, in others, it passes with the air into the high-pressure cylinder, and the heat of compression readily absorbs it again, passing it directly to the reservoirs. If an aftercooler (this is a nest of cold tubes of a construction exactly similar to that of the intercooler) is placed between the discharge pipe of the high-pressure cylinder and the reservoir or service lines, the temperature of the air will be suddenly reduced to normal, and most of the water will be deposited where it can be drained off easily. The idea is to insure the reduction of the temperature of the discharged air to normal before it enters the service pipes. Another way is to connect at least three reservoirs in series so that the air has to pass through all of them before entering the lines. This will collect the water very well, but it is necessary to drain the reservoirs frequently. See also Air Compression and allied subjects.

Compression. Compression in a steam engine acts in connection with the premature release in order to reduce the shock at the end of the stroke. During the forward stroke of an engine, the exhaust port in front of the piston remains open. Shortly before the end of the stroke, this closes, leaving a certain amount of steam in the cylinder. The continuation of the stroke compresses this steam, and by raising its pressure forms a cushion, which, in connection with the removal of the pressure back of the piston by release, brings the piston to a stop and causes it to reverse its direction without shock. High-speed engines require a greater amount of compression than those running at low speed.

Compression, Adiabatic. See Adiabatic Expansion and Compression.

Compression Coupling. A coupling provided with a split sleeve and two conical sleeves surrounding it. The sleeves are so arranged that when the two conical outside sleeves are drawn together by bolts and nuts, the inside split sleeve grips the two shafts to be coupled together and holds them firmly.

Compression, Isothermal. See Isothermal Expansion and Compression.

Compressometer. A compressometer is an instrument which is used to determine the elastic limit of a material under compression or the deformation under fixed increments of load. It is equipped with a micrometer indicating device.

Compress Polishing Wheel. The compress polishing wheel is a type of wheel in which the material, usually leather or canvas, is placed crosswise of the face of the wheel instead of the wheel being made up of parallel flat disks. The wheel consists of an angular ring, made up of rectangular pieces of material arranged radially and compressed to form a ring or "cushion" of polishing material one or more inches in depth. This cushion is assembled with side plates engaging annular recesses in the compressed ring. The side plates, in turn, are riveted to a hub.

Concatenation. A method of speed control sometimes called cascade control obtained by connecting alternating-current induction motors mounted on the same shaft. The primary of one motor is connected to the line while its secondary is connected to the primary of the other, and either motor may be provided with one or more windings, so as to change the number of poles. The secondary of the second motor is connected to a resistance which is eventually short-circuited. The operating speed corresponds to the sum of the number of poles on both motors and may be one-half, one-quarter, etc., the speed of either motor when running alone. The efficiency at these speeds is higher with this method than with the rheostatic method of control.

Concrete. Concrete consists of a mixture of sand, gravel, or broken stone and cement in various proportions. Water is added to this, which, when chemically combined with the cement, binds the whole mixture together into a solid mass having the characteristics of strong artificial stone. In proportioning the quantities of the various materials used, the object is to obtain a concrete in which the air spaces are as small as possible, and as the cement is by far the most expensive of the materials used, it is desirable to use as little of it as is consistent with strength. The amount of each ingredient is usually measured by volume, and the mixture is generally designated by stating the proportion of each ingredient in a given order, as "1 : 2 : 5," where the first figure indicates the proportion, by volume, of cement; the second, the proportion of sand; and the third, the proportion of stone or gravel; hence, 1 : 2 : 5 concrete is a concrete containing one barrel of cement, two barrels of coarse sand, and five barrels of gravel or broken stone.

Frozen Concrete: The freezing of concrete will not damage it, if it has first had a chance to set under favorable conditions for about two days. The effect of the freezing is simply to delay the process of hardening, which will again proceed under suitable conditions, and the concrete will eventually attain its full strength. If concrete is frozen before it has commenced to set firmly, it will not be injured, provided precautions are taken to prevent it from freezing again after it thaws until it is sufficiently hardened to withstand the effects of subsequent freezings. It is alternate freezing and thawing while setting that causes the damage. When concrete work is done in winter, it is necessary to devise means of mixing the concrete with materials freed of frost, placing it in the forms before it has commenced to freeze, and then protecting it and keeping it warm for about two days.

Concrete Mixing. In making concrete, the amount of mixing water controls the strength to such an extent that strength may be predetermined simply by regulating the amount of water relative to the quantity of cement. This predetermination of concrete strengths through the use of varying amounts of water is known as the "water ratio" method. This method insures uniform strength, regardless of changes in workability or in the sizes of the aggregates. For ordinary work, the proper amount of water to use is the smallest quantity that will give a mixture of good workability. Builders in general should use as dry a mixture as practicable.

Thorough mixing is another important point. Concrete should remain in the mixer for at least a minute, and most State Highway Commissions require at least 1½ minutes for mixing. The speed of mixing is not so important as the time, for materials

must be thoroughly blended to form good concrete. Dusty or dirty sand, gravel, or crushed stone aggregates will not make strong concrete. Frequently sand and pebbles must be washed as well as screened to remove clay and organic material. Although concrete should be mixed and placed in the forms as dry as possible, it requires frequent moistening to "cure" it properly. For instance, in highway building, a new concrete road is flooded with water for from ten to fourteen days or is kept moist by a covering of damp earth or straw.

Concrete Mixing Water: The Bureau of Standards recommends the use of a small quantity of calcium chloride in the mixing water of concrete in order to hasten the hardening of the concrete. Tests showed that the addition of calcium chloride to the mixing water up to 10 per cent by weight increases the strength from 30 to 100 per cent over that of concrete in which plain water is used, and that the best results are obtained when from 4 to 6 per cent of calcium chloride is used. While calcium chloride has no harmful effect upon the concrete, it does affect iron and steel, and therefore should not be used for reinforced concrete.

Concrete Mixtures. For water tanks and similar structures subjected to considerable pressure and required to be water-tight, mixtures rich in cement and composed of either 1 : 1 : 2 or 1 : 1½ : 3 concrete are used.

For reinforced floors, beams, columns, and arches, as well as for machine foundations which are subjected to vibration, a 1 : 2 : 4 concrete is generally used. This composition is also employed when concrete is used under water.

For ordinary machine foundations, retaining walls, bridge abutments, and piers in the air, a 1 : 2½ : 5 concrete is satisfactory, and for ordinary foundations, heavy walls, etc., a lean mixture of 1 : 3 : 6 concrete may be used.

Concrete Poles. Concrete poles for transmission lines are of three general types, known as solid, hollow, and trussed poles. In the United States, the majority of poles now in use are of the solid type, whereas in Europe hollow poles are used principally. Solid and hollow poles may have the same outward appearance, being either round, square, hexagonal, octagonal, or square with beveled corners. Reinforcing rods are placed near the outer surfaces, the number of rods varying with the size of pole and the load it must stand. Many square poles have only four rods, one being in each corner. Solid concrete poles have considerable flexibility and strength. A 35- or 40-foot pole fixed solidly in the ground for 6 feet of its length may be deflected from 6 to 8 inches and come back to its normal position, after removal of the load.

Concrete Strength. The compressive strength of concrete which, after having been mixed and laid, has set twenty-eight days, varies from 1000 to 3300 pounds per square inch, according to the mixture used. If made in the proportion 1 : 3 : 6 (one part cement, three parts sand, and six parts stone or gravel, by volume), using soft limestone and sandstone, a compressive strength of only 1000 pounds per square inch may be expected, whereas a mixture of 1 : 1 : 2, made with soft limestone and sandstone, will have a strength of 2200 pounds per square inch. A mixture of 1 : 3 : 6, made from granite or trap rock, will have a compressive strength of 1400 pounds per square inch, while a mixture of 1 : 1 : 2, made from granite or trap rock, will have a strength of 3300 pounds per square inch. Other mixtures will have values between those given. Concrete may be mixed with cinders, but, in this case, very inferior strength is obtained; the richest mixtures will give a strength of only about 800 pounds per square inch.

Condensation in Engine Cylinder. The principal waste of steam in steam engine operation is due to condensation during the stroke. This occurs because of the fact that during expansion and exhaust, the cylinder walls and head and the piston are in contact with comparatively cool steam, and, therefore, give up a considerable amount of heat. When fresh steam is admitted at a high temperature, it immediately gives up sufficient heat to raise the cylinder walls to a temperature approximating that of the entering steam. This results in the condensation of a certain amount of steam, the quantity depending upon the time allowed for the transfer of heat, the area of exposed surface, and the temperature of the cylinder walls. During the period of expansion the temperature falls rapidly, and the steam, being wet, absorbs a large amount of heat. After the exhaust valve opens, the drop in pressure allows the moisture that has collected on the cylinder walls to evaporate into steam, so that, during the exhaust period, but little heat is transferred. With the admission of fresh steam at boiler pressure, a mist is condensed on the cylinder walls, which greatly increases the rapidity with which heat is absorbed. The amount of heat lost through cylinder condensation is best shown by a practical illustration. One horsepower is equal to 33,000 foot-pounds of work per minute, or $33{,}000 \times 60 = 1{,}980{,}000$ foot-pounds per hour. This is equivalent to $1{,}980{,}000 \div 778 = 2550$ heat units. The latent heat of steam at 90 pounds gage pressure is 885 heat units; hence, $2550 \div 885 = 3$ pounds of steam at 90 pounds pressure required per horsepower, provided there is no loss of steam, and all of the contained heat is changed into useful work. From 30 to 35 pounds of steam are required in the average simple non-condensing high-

speed engine. The most effective method of reducing condensation losses is by so designing the engine that expansion occurs in two or more stages as in compound and triple-expansion engines.

Condensation in Steam Mains. When steam is turned into the piping system, part of it comes in contact with the inner surface of the pipe and fittings, thus transferring part of the heat to the metal of the pipe, from which it is transferred to the atmosphere surrounding the pipe. As the air near the outside surface of the pipe becomes heated to a higher temperature than that of the surrounding air, it quickly expands and rises, thus making room for cooler air which is, in turn, heated and rises, carrying the heat away with it. In this way, a continuous stream of cool air passes over the surface of the steam pipes, causing part of the steam to condense, or change back into the form of water. The condensation that occurs when steam fills the pipe, but is not flowing through it, is known as "static condensation," and that which occurs while the steam is flowing, is known as "dynamic condensation." The amount of condensation has been found to be practically the same in both cases. In order to prevent excessive heat radiation and the resulting condensation losses, the steam piping system should be well covered or lagged with a good grade of non-conducting covering material. No matter how carefully the steam piping is covered, however, some water is still likely to accumulate in the system, due to condensation; therefore, the piping should contain no low spots or pockets in which water can collect.

Condenser. The purpose of attaching a condenser to a steam engine or turbine is to obtain a reduction in the back pressure, on the exhaust side, by the formation of a partial vacuum in the chamber into which the engine exhausts. The effect of a condenser is either to increase the power of an engine at a given steam consumption or to reduce the steam consumption for a given power. Condensers may be divided into two general classes: In one class the condensing water is mixed directly with the steam, and in the other class the condensing water and steam are kept separate, condensation being effected by contact of the steam with metallic surfaces which are cooled by the continuous circulation of the water. The first class includes jet condensers, barometric or siphon condensers, and the ejector type, whereas, in the second class are the different designs of surface condensers.

Jet Condensers: In a jet condenser, the steam and condensing water mingle in the condensing cone, and the condensed steam is discharged with the water. As the condensing water acts directly upon the steam by actual contact, it will produce a greater drop in pressure for a given amount of water than when used in a surface condenser.

Surface Condenser: In the operation of a surface condenser, the exhaust steam from the engine enters the shell at the top and fills the condensing chamber, flowing around and among the tubes, while the cooling water is made to pass through them by means of the circulating pump. The steam is condensed by contact with the cold surfaces of the tubes, and drops to the bottom of the shell where it flows to one end and enters the air or vacuum pump and is discharged into the hot-well.

Barometric or Siphon Condensers: The barometric or siphon condenser is particularly adapted to plants in which the condensing water is suitable for boiler feeding, and also to any plant where condensation of steam only is desired, the condensing water not being used. In operation, the condensing water passing through the annular orifice formed by the nozzle flows downward in a cone-shaped film into the combining tube, where its velocity is sufficiently increased to enable it to carry air along with it, thus producing a vacuum in the steam exhaust pipe. The steam flows downward through the regulating nozzle and into the cone-shaped film of water where it is condensed.

Ejector Condenser: The ejector type of condenser is so constructed that the exhaust steam from the engine passes through a series of inclined nozzles and mixes with a stream of condensing water that flows through the nozzles. Ejector condensers may be utilized to draw up the condensing water. The exhaust steam moves with considerable velocity and, when the steam and water meet, the steam is condensed and flows downward with the moving column of water into the hot-well. The discharge end of the pipe is sealed by the water in the hot-well and the velocity of flow overbalances the pressure on the well.

Condenser, Electrical. An electrical condenser, also called a capacitor, is a device for accumulating a large quantity of electricity in static form. Conductors separated by some non-conducting material, called dielectric, form a condenser. A simple form of condenser consists of a large number of sheets of tin foil separated by alternate insulating sheets, such as wax paper or mica. Every other sheet of tin foil is connected together, forming two sets of condenser "plates" and each set is connected to a terminal. If these two terminals are connected with a battery or other source of direct current, an electrostatic charge will be stored up in the condenser. If the battery is disconnected and the condenser terminals connected, the charge will flow out, resulting in a current of short duration. The condenser seems to acquire a counter-electromotive force which becomes equal and opposite to that of the connected battery.

When connected in an alternating-current circuit, although no actual current can flow between the two sets of sheets or plates

because of the insulating material between them (except that due to leakage since no material is a perfect insulator), the alternating rise and fall of potential on one side of the condenser will cause a similar rise and fall of potential on the other side of the condenser. Thus, alternating-current power may be transmitted through it. The effect of a condenser in an alternating current circuit might be compared to a flexible disk or membrane in a pipe line which transmitted any fluctuations in pressure without permitting the actual flow of water.

Condensers may be divided into different classes according to the kind of dielectric used, such as air, glass, mica, paper, and electrolytic condensers.

Air condensers are most familiar in the form of variable condensers with aluminum plates used for tuning in a radio set.

Glass condensers are especially adapted to high voltages. The Leyden jar is a well-known form of glass condenser.

Mica condensers are widely used in high-voltage circuits for both power and communication purposes. They are, however, seriously affected by the presence of moisture or any imperfections of the mica surfaces.

Paper condensers are more widely used than any other type. They are generally constructed with metallized paper, tin foil or aluminum foil as "plates" and are impregnated with paraffin or special wax preparations to keep them moisture-proof.

Electrolytic condensers are constructed of metal plates, usually aluminum or tantalum placed in a suitable electrolyte. When placed in this electrolyte, they become coated with a film which is capable of conducting current more freely in one direction than in the other. Below their breakdown voltage, they can hold a large charge in proportion to their conductor surface and this characteristic makes them useful in filter or radio circuits, where large capacitance is needed in compact form. They are, however, very sensitive to temperature changes and operate with a relatively high power loss.

Condenser, Synchronous. When a synchronous motor is operated idly, that is, without carrying any mechanical load, and simply supplies a wattless current for correcting the power factor of an installation, it is termed a *synchronous condenser.* It is used for power-factor correction and for maintaining constant voltage by power-factor control.

Condenser Tubes. Seamless brass condenser tubes, according to A.S.T.M. Specification B55-33, have the following composition, in per cent: Copper, not less than 70; lead, not over 0.075; iron, not over 0.06; zinc, remainder.

Condensing Water Cooling Tower. See Cooling Towers.

Condensite. Condensite is a hard substance used as an electrical insulating material. The chief constituent of condensite is a resinous gum, made by the reaction between phenol and formaldehyde, condensite being produced by combining this gum with a hardening agent at high heat. The advantages of this insulating material are that it is non-inflammable, infusible at any ordinary temperatures, insoluble in oil and in most acids and other solvents, and that it shrinks only 0.2 per cent in molding. It can be used either for plastic molding, or for impregnating wood, paper, cardboard, rubber, leather, etc., or as a cement for fastening together the parts of porcelain insulators, for sealing terminals in porcelain bases, etc. A thickness of 3/16 inch of this material has a puncturing voltage of about 12,000 volts. At a temperature of 170 degrees F., this is reduced to about 5000 volts.

Conductance. Conductance is the property of an electric circuit, or of a body that may be used as part of an electric circuit, which determines, for a given electromotive force in a circuit or for a given potential difference between the terminals of a part of a circuit, the rate at which electrical energy is converted into heat. It is equal to the power which is converted divided by the square of the potential difference, and it is also equal to the reciprocal of the resistance.

Conduction. The passage of heat from one body to another, or from one part of the same body to another part at a lower temperature, is called *conduction*. Heat from the furnace reaches the water within a boiler by conduction through the plates, and is diffused throughout the entire volume by the same process, assisted by *convection*. Heat which is transmitted through the air by the vibration of the surrounding ether is called *radiant heat*. This does not warm the air directly, but is absorbed by the objects in its path, which, in turn, give it to the air by conduction. Much of the heat absorbed by the plates directly above the fire in a boiler is radiant heat.

Conductivity. Conductivity may be defined as the capacity of any substance to conduct an electric current. The conductivity depends largely upon the physical state of the substance. For instance, the conductivity of air decreases very rapidly as its pressure increases, while rarefied air makes a good conductor of electricity. The conductivity of all substances materially alters with a change of temperature, usually decreasing as the temperature increases. The substances which are used for conductors of electricity in commercial work are limited to copper, aluminum, iron and some of their alloys. Of these, the first is pre-eminently the best, while next in order comes aluminum. See Copper Conductivity; also Conductor Materials.

Conductor. A conductor, in the sense in which this word is used in electrical engineering, is a wire or combination of wires not insulated from one another and used for carrying an electric current. Where one or more conductors are insulated from one another but held in the same covering or casing they are usually termed a cord or cable.

The maximum current which a conductor can safely transmit is known as its *carrying capacity*. Heat is developed whenever an electric current flows through a conductor, the amount being directly proportional to the resistance of the conductor and the square of the flowing current. The allowable safe temperature rise is one of the limiting features of the current-carrying capacity of any conductor, and, if the heat develops faster than it can be dissipated from the surface, the temperature will rise. See also Kelvin's Law.

Conductor Materials. The materials most commonly used for electrical transmission are copper and aluminum. Of the two, copper is the better material and is used most extensively. It has a higher conductivity, greater mechanical strength, greater durability, is more ductile, and is not so easily damaged in handling. For sizes of the same conductivity, aluminum wire has about one-half the weight of copper but the diameter is 1.37 times that of copper; consequently aluminum wire exposes a greater surface to wind pressure, and for sleet to form upon, and thereby imposes greater strains on the supporting poles or towers, and limits it use to shorter spans than can be used with copper. Because of the larger diameter and lightness, aluminum conductors are useful for transmitting power at high voltages which would produce a large corona loss with copper conductors having the same conductivity as aluminum. One of the greatest disadvantages of aluminum for conductors is that it has less mechanical strength than copper. This necessitates either using greater sags and higher poles or towers, or spacing the towers closer together. In either case, the cost of the supporting structures is greater than with copper conductors, and this greater cost will usually more than offset the saving gained by the lower cost of the aluminum conductors. In order to take advantage of the larger bulk and lightness of aluminum, and yet have mechanical strength equal to, or greater than, copper, a composite cable has been put into commercial use. This cable consists of a center core of high strength steel wire wrapped with a number of strands of aluminum wire. The steel is depended upon for the greater part of the supporting strength, although the aluminum wires aid somewhat. In addition to copper and aluminum, bi-metallic copper-steel and steel wires are used. They have lower conductivity than the cop-

per or aluminum, but have greater mechanical strength, and are used for long spans across rivers, etc., for overhead ground wires, and for short lines in which the power to be carried is so small that, if copper wires were used, they would have to be unnecessarily large for mechanical reasons. Bi-metallic wire is a composite wire having a steel center and a copper coating.

Conductor Sizes, Stranded. See Stranded Conductor Sizes.

Cone Clutch. A friction clutch in which one friction surface is in the form of a frustum of a cone and which, for engagement, is forced into the other member which is made to fit it on the inside. One friction surface may be covered with leather. If the angle of the conical surface of the cone type of clutch is too small, it may be difficult to release the clutch on account of the wedging effect, whereas, if the angle is too large, excessive pressure will be required to prevent slipping. The minimum angle for a leather-faced cone is about 8 or 9 degrees and the maximum angle about 13 degrees. An angle of 12½ degrees appears to be the most common and is generally considered good practice. These angles are given with relation to the clutch axis and are one-half the included angle.

Cone Muff Coupling. A coupling consisting of a split sleeve each end of which is cone-shaped on the outside and which surrounds the two ends of the shafts to be coupled together. The sleeve is surrounded by two rings, one on each end, having tapered bores fitting the conical ends of the sleeve. These two rings are clamped together by means of bolts and nuts and in clamping the rings together the split sleeve is forced to bind firmly over the two shafts. See also Compression Coupling.

Cone-Pulley. A cone-pulley is, in reality, a stepped-pulley having, usually, from three to five different diameters for securing a like number of speed variations by shifting a belt from one "step" to another, cone-pulleys being used in pairs with the largest step of one cone-pulley opposite the smallest step on the other cone-pulley. Usually cone-pulleys are made with uniform steps; that is, the difference in diameter between the various steps is the same. When the centers of the shafts on which the cone-pulleys run are a fair distance apart, so that the belt passes very nearly halfway around each of the cones on which it is running, this method of making the cone-pulleys will prove satisfactory. The length of the belt will then be approximately equal to twice the distance between the shafts added to half the circumference of the step on one of the cones on which the belt is running, plus half the circumference of the step on the other cone engaging with the belt. When the shafts are nearer together, however, so that the belt makes a large angle with

the line passing through the centers of the cones, or when there is a large difference between the largest and the smallest steps of the cone, it is not possible to obtain satisfactory results by merely designing the two pulleys with equal differences between the steps, because the length of belt required on the largest and smallest steps will be different from the length required on the two middle steps.

Connecticut River Rule. A rule employed for finding the board measure of logs. It is as follows: Deduct 4 inches from the diameter of the log, square one-fourth of the remainder, and multiply the result by the length of the log in feet; usually the diameter inside of the bark at the small end is measured.

Connection Bars. The name "connection bars" is usually applied to all connections on switchboards, between apparatus and bus-bars, and between different devices comprising the switchboard equipment. Wire is generally used up to 260 amperes, above which size bars are almost invariably used. Connections are usually bare up to 650 volts; above this voltage and up to 13,200 volts, they are usually insulated; above 13,200 volts, they are, as a rule, bare, and it is considered safer to warn the attendant to keep away from such conductors rather than to depend upon insulation which may deteriorate.

Conservation of Energy. Energy exists in various forms, such as mechanical, molecular, and chemical energy. It is stored in all kinds of fuel, and is made apparent by chemical reactions, by muscular effort, and by other means. Heat is a form of energy and the potential heat energy in coal originally was received from the sun. According to the important law of the conservation of energy, the latter may be transformed directly or indirectly from any one form into any other form, but the total amount of energy must forever remain the same. Energy can neither be created nor destroyed which accounts for the fact that "perpetual motion" is impossible. The various processes by which energy is utilized are simply means for transforming it from one form into another. The steam engine changes heat energy into mechanical energy, and the percussion of a bullet against a rock converts mechanical into heat energy. A body just at the point of falling from an elevation has a store of potential energy. As it falls its velocity increases, and its potential energy is gradually changed into kinetic energy.

Conservation of Mass. A chemical law applying to all chemical reactions, which states that whenever a change in the composition of substances takes place, the amount of matter after the change is the same as before the change.

Constantan. The alloy known as *constantan* is used for resistance wire in electrical instruments, and also to form one element in base-metal thermocouples. It contains about 60 per cent of copper and 40 per cent of nickel. Its electrical conductivity is only about one-thirtieth of copper; hence, its value as a resistance wire. Its resistance is quite stable over a wide range of temperatures as indicated by its low temperature coefficient of resistance which is about $\pm$ 0.00001 per degree C.

Constants in Mathematics. A constant is a value that does not change or is not variable. However, constants at one stage of a mathematical investigation may be variables at another stage, but an *absolute constant* has the same value under all circumstances. The ratio of the circumference to the diameter of a circle, or 3.1416, is a simple example of an absolute constant. In the common formula used for determining the indicated horsepower of a reciprocating steam engine, the product of the mean effective pressure, the length of the stroke in feet, the area of the piston in square inches, and the number of piston strokes per minute is divided by the constant 33,000, which represents the number of foot pounds of work per minute equivalent to one horsepower. Constants occur in many mathematical formulas and frequently a single value or constant represents one or more other values which have been eliminated to simplify the formula. For example, when there is a constant in both numerator and denominator, the formula may be simplified by dividing the numerator constant into the denominator constant, thus eliminating the former.

Contactors. The magnetically-operated switches of which magnetic control equipments principally consist are known as "contactors." This term is very generally understood as applying to a switch which closes by the application of current to a magnetic coil and is held closed by the continued application of current to the same coil. Complete lines of contactors have been developed, both for direct and alternating current, which are applicable, by the use of suitable auxiliaries, to any required arrangement of motor circuits. Contactors are designed to operate many thousand times without replacement of electrical parts, and several million times before wearing out mechanically.

Continuous Milling. In any scheme of so-called "continuous milling" the object is to keep the cutters at work the maximum time possible. Continuous milling machines are of the rotary work-table and planer-table types. The rotary table machine is set with its table axis either vertical or horizontal, the work being spaced compactly around the table, and the successive parts milled as they are fed past the revolving cutters. The vertical-

axis type has the advantage of easy loading and inspection of the cutter at work, while the horizontal-axis table can be made to work between opposed cutters, which mill the pieces on both ends simultaneously and to length.

The planer-table type of machine may be used for continuous milling in several ways. The work pieces may be strung on the table and milled with the table feeding "against the cutter" until the limit of traverse is reached, the feed then being reversed to travel "with the cutter," after which the work is removed. The objection to this method is the difference in cutter action on the forward and return feed. Another method is to remove parts as soon as they are milled and then return the table by a quick traversing motion. Still another method of continuous milling on planer-type machines is known as the removable platen method. The work is loaded onto a short platen held on a bench alongside of the machine; the platen is then hoisted and lowered onto the ways. A rack on the under side engages the longitudinal feed-screw and feeding toward the cutter begins. Meanwhile, a platen ahead carrying similar parts has passed beyond the cutters and is ready to be unloaded. This is hoisted and trolleyed to the head end of the machine and lowered onto the bench, where the work is removed and more pieces put on. The operation is thus kept up continuously. The minimum number of platens required is two, but three, four or five are often used.

Contracting Chill. A metal mold used for making chilled cast-iron car wheels which is so designed that when the molten metal is poured into it, the entire surface will contract, decreasing the diameter, and thus following up and remaining in contact with the shrinking metal of the cooling wheel.

Contracts, Royalty. See under Royalties on Patents.

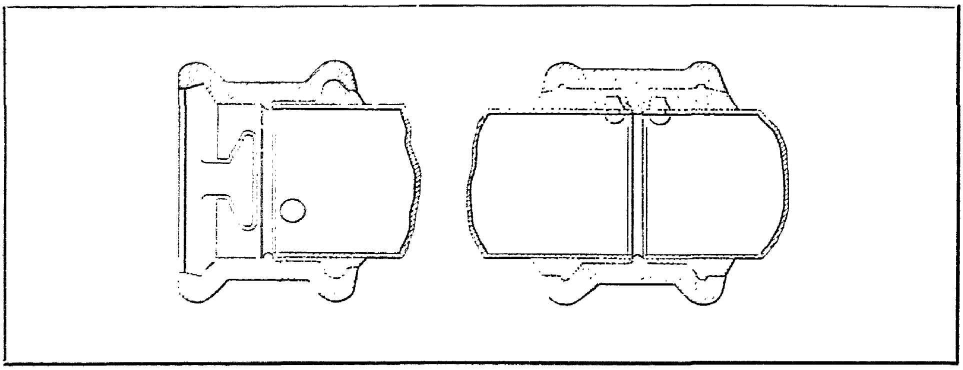
Controller, Electric. An electric controller is a device or group of devices, which serves to govern, in some predetermined manner, the electric power delivered to the apparatus to which it is connected. Included within this definition are the various types of devices used to start, stop, reverse, and control the speed of electric motors. Controllers may be classified as manual, semi-magnetic, and fully magnetic. See also Motors, Control Equipment.

Control Switches. A control switch is used to control the operation of a remote control device, such as a motor or solenoid-operated oil switch, a circuit-breaker, or a rheostat, or a governor motor of a steam engine, water turbine, or other prime mover. It may also be used to close or open circuits, to trip circuit-

breakers, oil switches, etc., from some distant point. Control switches are made up in several different forms, such as the plain lever switch type, the drum controller type, and the pull-and-push-button type. They may be single-throw or double-throw, and either single, double, or triple pole, depending upon the service for which they are intended. These switches are usually of small current capacity (under 50 amperes) and are not, in general, called upon to break much current.

Convection Currents. The currents set up within a liquid, due to temperature difference in different parts, are called *convection currents,* and are important in causing the water to circulate over the heating surfaces within a steam boiler. See also Conduction.

Converse Lock-Joint. The Converse lock-joint is a leaded joint used for water piping which does not have to stand very



Converse Lock-joint

high pressure. The joint consists of a special cast-iron coupling or hub (see illustration) into which the ends of the pipes to be joined are fitted. This hub has an annular groove at each end and, in addition, two T-shaped grooves, one of which is shown in the illustration to the left. The pipe has two holes punched a short distance from the end on opposite sides into which rivets are driven. One of the holes for the rivets is shown in the illustration to the left, while the rivets themselves are indicated in the section to the right. In making this joint, the heads of the rivets slip into the T-shaped slots of the hub, after which the pipe is turned slightly, locking the pipe into the hub, and preventing it from being pulled out endwise. The joints are then made tight by pouring lead into the annular groove and calking.

Converter. A large pear-shaped vessel holding from ten to fifteen tons of molten iron, employed in the *Bessemer process*

for converting pig iron into steel; or the barrel- or trough-shaped vessel used in the refining of copper by a method known as the *Manhes* or *converter process*.

Converters, Synchronous. See Synchronous Converters.

Conveyor. A device for handling and conveying heavy and bulky materials, such as coal and ore, as well as small machine parts of various description, from one part of a plant to another. Conveyors are constructed either to move the material horizontally or to raise it to a higher level. There are different classes of conveyors. See Belt Conveyors; Bucket Conveyors; Screw Conveyors.

Coolant. The term "lubricant" is commonly applied to a fluid used on metal-cutting tools, but as the cooling action of this fluid is by far its most important function, the term "coolant" is more strictly accurate and is now used quite generally. See Cutting Oils and Compounds.

Cooling Towers. From 20 to 30 per cent may be saved in fuel by the use of a condenser, assuming that the water used for condensing the steam can be obtained free of cost. When a power plant is located in a city where the water must be obtained at regular city rates, it may be more economical to run non-condensing than to purchase cooling water. In order to do away with the water expense, so-called *cooling towers* are extensively used. By means of these towers, the condensing water may be cooled and used over and over again with a comparatively small loss by evaporation. There are various forms of cooling towers in use but the general principles are practically the same in each case. The tower, generally, consists of a steel shell inside of which are suspended a number of mats of a special steel wire cloth, galvanized after weaving. The mats are, in effect, a metallic sponge, capable of holding a large quantity of water in suspension which accumulates and drips off into the reservoir at the bottom. The water to be cooled is pumped to the top of the tower and discharged through a number of distributing nozzles upon the tops of the mats. From here it drips to the bottom, exposing a large surface to the air which may be forced upward by fans placed at the bottom of the tower. Towers are also made for natural draft, in which case the flue is extended to a considerable height above the cooling surfaces.

Coordinates. In analytical geometry, coordinates are the distances, measured parallel to the coordinate axes, which locate a point. In plane analytical geometry, there are two coordinates, the *abscissa* and the *ordinate*. In analytical geometry in three dimensions, there are three coordinates.

Copal. Copal is a resinous product used as an electrical insulating material in the form of a colorless varnish obtained by dissolving in alcohol, turpentine, or linseed oil. As an insulating material, it has several disadvantages, however, because it melts at a low temperature, it is very inflammable, and it is brittle, when cold. The puncturing voltage is about 10,000 volts for a thickness of about 1/8 inch, and 20,000 volts for a thickness of about 1/4 inch.

Cope. In foundry practice, the cope is the upper part of a flask used for molding.

Copper. Copper is a very malleable ductile metal that is widely used. The specific gravity of pure copper is 8.94, but varies between 8.91 and 8.95, according to the treatment to which it may have been subjected. Ordinary commercial copper is somewhat porous and the specific gravity ranges all the way from 8.2 to 8.8. The melting point of pure copper is 1083 degrees C. (1980 degrees F.), but ordinary commercial copper will melt at a somewhat lower temperature, usually about 1940 degrees F. The linear expansion per unit length per degree F. is 0.00000887. The specific heat at 32 degrees F. is 0.0899, and at 212 degrees F., 0.0942. In heat conductivity, copper ranks next to silver, and is superior, in this respect, to all other metals. The heat conductivity is 73.6 per cent of that of silver. In electrical conductivity copper also ranks next to silver, and if the conductivity of silver is assumed as equal to 100, that of copper varies from 96.4 to 97.7, according to its condition.

There are several hundred copper minerals, but the more important ores are not more than about a dozen in number. The most important are the sulphide ores. There are three methods by means of which copper may be obtained from its ores: The first of these methods, the dry method, cannot be profitably employed for ores containing less than 4 per cent of copper. This method is frequently referred to as copper "smelting." The second method, the wet method, is preferred for ores that are very poor in copper, that is, those that contain less than 4 per cent of metal. The third or electro-metallurgical method is very largely used for all classes of ores, but especially for ores containing a comparatively small amount of precious metals, as in this case the ore may be profitably subjected to an electrolytic treatment, the copper being recovered together with the silver and gold present in the ores.

The tensile strength of cast copper varies from 20,000 to 30,000 pounds per square inch; the compressive strength is about 40,000 pounds per square inch; and the modulus of elasticity, 10,000,000. Annealed copper wire has a tensile strength of

35,000 pounds per square inch, and a modulus of elasticity of 15,000,000; unannealed wire has a tensile strength up to 60,000 pounds per square inch, and a modulus of elasticity of 18,000,000.

Copper Alloys. There are many different non-ferrous alloys which contain copper as the chief alloying element. These include many brass and bronze compositions for various purposes. See Brass Alloys for Castings; Brass Sheets; Brass Wire; Brass Rod; Bronze; Admiralty Metal; Aich Metal; Ajax Metal; Baily's Metal; Bell Metal; Benedict Metal; Bismuth Bronze; Chinese Alloys; Constantan; Delta Metal; Dutch Metal; Electrolytic Copper; English Gear Bronze; Gurley's Bronze; Japanese Alloys; Muntz Metal; Ounce Metal; Plastic Bronze; Red Brass.

Copper Alloy Steel. A steel containing a small percentage of copper and nickel, and sometimes chromium, which has been found suitable as a substitute for more expensive alloy steels. A steel containing from 1.5 to 1.8 per cent of nickel and from 0.5 to 0.8 per cent of copper is equal in its properties to a 3 per cent nickel steel. If 0.5 per cent of chromium is added to this alloy steel, the physical properties will equal those of nickel-chromium steel containing 3 per cent of nickel and 1 per cent of chromium.

Copper-Aluminum Alloy. An alloy containing about 90 per cent of copper and 10 per cent of aluminum is remarkable for its high tensile strength, its resistance to corrosion, and its wearing qualities. It is used for worms, accurately fitted bearings, and in places where ability to resist the corrosive action of salt water, and tanning and sulphite liquids is required. The physical properties resemble those of 0.35 per cent carbon Bessemer steel, and are about as follows: Ultimate tensile strength, 70,000 pounds per square inch; elongation in two inches, 20 per cent; reduction in area, 21 per cent; specific gravity, 7.5; Brinell hardness number, 500-kilogram load for 30 seconds, from 90 to 100; shrinkage allowance, 0.22 inch per foot; elastic limit, in compression, 19,500 pounds per square inch. This bronze is about 10 per cent lighter than either yellow brass or manganese-bronze; 17 per cent lighter than phosphor-bronze; and 15 per cent lighter than red brass.

Copper Blast Furnace. A blast furnace used for smelting copper ore. It is much smaller in size than the blast furnace used for iron ores. The furnace is made either round or rectangular in section, the round furnace being used for outputs from 50 to 70 tons a day, and the rectanglar furnace for larger amounts. The round furnace may be up to 4 feet in diameter and is made 14 feet high. Rectangular furnaces are made not

more than 4 feet wide and are also made 14 feet high, but are made as long as required.

Copper Castings. So-called "pure copper" castings ordinarily contain from one to three per cent of zinc. These are used in electrical installations and for die-blocks on electric welding machines. The conductivity, as compared with silver = 100, is not more than 60 per cent. Pure commercial copper containing from 99.6 to 99.9 per cent of metallic copper has a conductivity from 70 to 85 per cent of that of pure silver. Hence, the impurities in ordinary copper castings impair, to a great extent, its value as an electrical conductor.

Copper-Clad Steel. A material generally used in the form of wire, in which a steel wire is covered with a coating of copper. It is produced either by alloying the copper with the surface of the metal or by welding it onto the surface. When the copper is alloyed with the surface, it is brought to a molten state before being applied, while, when welded to the surface, it is merely in a plastic state.

Copper Coloring. To color copper articles, such as ash trays, pin dishes, receivers, etc., a solution of ammonium sulphide will give good results for the beginner. The greatest variety of colors, from light brown to black, can be obtained by this simple method. Use a dilute solution, cold. A good working solution is produced by diluting a saturated solution of ammonium sulphide with from 10 to 40 parts of water. A light brown color is produced by dipping the work for a very short time in the solution, withdrawing it, and allowing it to dry in the air. A darker shade of brown is obtained by a longer immersion, according to the color desired, after which the work is allowed to dry in sawdust. To obtain a black coloring, allow the article to remain for some time in the bath, and, after removing, dip it in alcohol, after which the alcohol is burnt off, leaving a black coating. These colors can be permanently fixed by a transparent lacquer. The objection to ammonium sulphide is the great care necesary in handling, as it leaves an indelible stain upon the fingers, and also has a very obnoxious odor. The ammonium sulphide also decomposes in time, depositing sulphur. It should be kept in a dark-colored bottle provided with a glass stopper. It is not good for brass, being adapted only for copper.

Another solution for coloring copper which yields very good results is composed of copper nitrate, 1 part; water, 3 parts. This solution forms a deposit of copper salt, and, if heated, the salt is decomposed into a black copper oxide. The greenish tints are obtained by the following solution: Ammonium carbonate, 2

ounces; ammonium chloride, 2/3 ounce; water, 16 ounces. This solution gives good results on both copper and brass, different colorings being obtained by repeated dippings in the solution, allowing ample time between each for the articles to properly dry.

Copper Conductivity. The following are the normal values for standard annealed copper according to the Standardization Rules of the American Institute of Electrical Engineers.

1. At a temperature of 20 degrees C., the resistance of a wire of standard annealed copper one meter in length and of a uniform section of 1 square millimeter is $1/58$ ohm $= 0.017241$ ohm.
2. At a temperature of 20 degrees C., the density of standard annealed copper is 8.89 grams per cubic centimeter.
3. At a temperature of 20 degrees C., the "constant mass" temperature coefficient of resistance of standard annealed copper, measured between two potential points rigidly fixed to the wire, is $0.00393 = 1/254.45$ per degree centigrade.
4. As a consequence, it follows from (1) and (2) that, at a temperature of 20 degrees C., the resistance of a wire of standard annealed copper of uniform section, one meter in length and weighing one gram, is $1/58 \times 8.89 = 0.15328$ ohm.

Copper Hardening. It is quite commonly believed that the hardening of copper as practiced by the ancients is a "lost art," but present-day metallurgists not only understand how the ancients hardened their copper and bronze, but also know how to produce copper and bronze products that are even harder than specimens which have been discovered. Cutting edges on swords, daggers, knives and other implements developed by the ancients were obtained by hammering the metal, or, in other words, cold-working. These old metal-workers not only hand-hammered their copper implements but also used the same means to harden bronze articles.

There are two methods of hardening copper. One consists of alloying the copper with some other metal or several other metals, such as zinc, tin, nickel, cadmium, chromium, cobalt, silicon, aluminum, iron, beryllium and arsenic; the second consists of cold-working the metal or copper alloy. In fact, it is possible to work the metal to such a state of hardness that a slight amount of additional work will cause it to break. The explanation of all copper hardening may be attributed to one of these methods or a combination of both. Photomicrographs of an ancient copper spear-head indicate that apparently this hardness had been obtained by cold-working. It is possible to produce copper scissors, knives, and other cutting tools, but unless a special reason exists for their use, they offer no advantages over tools made from steel. The actual hardness of an-

nealed commercial copper as determined by the Brinell machine is from 40 to 50. The hardness of cold-worked pure copper probably does not ever exceed 120 Brinell. The hardness of copper that has been alloyed with some other metal or a number of metals rarely exceeds 250 Brinell, although a hardness just over 300 has been attained as an upper limit. As a basis of comparison, the Brinell hardness of very "soft" iron is around 80, and of steel used in common cutlery, such as in a pocket-knife, about 420 Brinell.

Coppering Solution. A coppering solution for coating finished surfaces, in order that lay-out lines may be seen more easily, is composed of the following ingredients: To 4 ounces of distilled water (or rain water) add all the copper sulphate (blue vitriol) it will dissolve; then add 10 drops of sulphuric acid. Test by applying to a piece of steel, and, if necessary, add four or five drops of acid. The surface to be coppered should be polished and free from grease. Apply the solution with clean waste, and, if a bright copper coating is not obtained, add a few more drops of the solution; then scour the surface with fine emery cloth, and apply rapidly a small quantity of fresh solution.

Copper Loss. The loss of energy which takes place when a current passes through a conductor, whether an armature winding or a transmission wire, is called *copper loss.* It is due to the resistance of the wire which causes a partial transformation of electrical energy into heat energy. The loss may be computed by multiplying the square of the current in amperes by the resistance of the conductor in ohms. The loss is then obtained in watts.

Copper Wire Strength. The strength of copper wire can be greatly increased by proper methods in the drawing operation. It has been found that the strength can be increased nearly 100 per cent by omitting the annealing process during the latter part of the drawing, at the same time making the steps of gradations between the successive dies smaller. In this manner, copper wire will obtain a very hard surface, and is known as "hard drawn." The increase in strength is greater for smaller diameters, as the treatment will affect a proportionately larger part of the cross-section. A No. 8 copper wire (0.165 inch in diameter) can be given a strength of 62,000 pounds per square inch of cross-section, while a No. 12 wire (0.104 inch in diameter) may obtain a strength of 64,500 pounds per square inch. As ordinary commercial copper wire has a tensile strength of only 32,000 pounds per square inch, the effect of correct methods in drawing is very marked. The modulus of elasticity is increased by these methods from 12,000,000 to 19,000,000 pounds, but the

elongation is reduced from 35 to 1.25 per cent. It should be noted that this change is effected entirely by manipulation in the drawing, and not by the addition of any alloying metal.

Coprtex. Heat-insulating cement made from a base material of resilient long-fiber copper slag wool. The cement will bond and stick to clean surfaces of any type of material. Average adhesive strength, 30 pounds per square inch. It will withstand a temperature of 2000 degrees F. The high-temperature Coprtex blocks weigh 22 pounds per cubic foot; their maximum temperature limit is 1800 degrees F. The cement is suitable for making repairs or changes in steam lines, headers, boilers, or similar equipment. High-temperature blocks may be used where superior insulating efficiency is required.

Cord. In the measure of wood, a cord, equals a pile 4 by 4 by 8 feet, or a cubical content of 128 cubic feet.

Cordeaux Thread. The Cordeaux screw thread derives its name from John Henry Cordeaux, an English telegraph inspector who obtained a patent for this thread in 1877. This thread is used for connecting porcelain insulators with their stalks by means of a screw thread on the stalk and a corresponding thread in the insulator. The thread is approximately a Whitworth thread, 6 threads per inch, the diameters most commonly used being 5/8 or 3/4 inch outside diameter of thread; 5/8 inch is almost universally used for telegraph purposes, while a limited number of 3/4-inch sizes are used for large insulators.

Core Boards. See Cores for Molds.

Core-Boxes. See Cores for Molds.

Core Loss. The power lost in an iron core of an electrical machine on account of hysteresis and eddy-currents, taken together, is called *iron loss* or *core loss*. These losses bring about a lowering of the efficiency of the machines, and also cause a heating up of the iron, and thus limit the permissible flux density, or make extra provisions for ventilation and cooling necessary.

Core Print. Many patterns for use in making castings, have projections which form pockets in the mold which can be used in supporting cores to form interior openings in the castings. These projections are called *core prints* as they leave a print or impression in the mold. The core, which has extensions for entering these prints, is made in a separate wooden mold or core-box and it is reinforced with iron rods or wire and baked in an oven to give it greater strength. There are three types of core prints in general use on patterns. Those that are placed

on the cope and drag side of a pattern are called *cope* and *drag prints;* those located on the sides or ends, or in any position where there is a joint or parting, are known as *joint* or *parting prints;* and those which are so placed that no parting can be made are called *tail, heel,* or *drop prints.*

Cores for Molds. Cores for forming passages or openings in castings are of three kinds: 1. Metal cores. 2. Dry sand cores. 3. Green sand cores. A *metal core* is used in brass or non-ferrous metal work when considerable accuracy in the core is required. Cores of this kind are not used in cast-iron molding. A *dry sand core* is one that is made from a fairly coarse sand free from clay, the sand being mixed with a bond or binder until it is of about the consistency of heavy flour dough. It is then baked until perfectly dry and hard. A *green sand core* is one which is made from ordinary molding sand—green sand—and which is not baked. This is, by far, the cheapest form of core which can be used, but it is restricted to comparatively simple shapes—usually plain cylindrical shapes—or to pattern forms in which there is a recess, so that the core can be shaped by molding the sand in connection with the regular molding work.

Oil-sand Cores: For certain classes of core work, excellent results are obtained by the use of sea sand and oil, such as, for instance, the core required for the combustion chamber of a gas or oil engine, or the steam ports of cylinders, when the core is entirely surrounded, and good venting is necessary. Oil-sand cores are very hard and strong, when dry. The principal objection to this kind of core is the disagreeable odor emanating from the oil. The fact that the oils generally used are fish oils is responsible for this odor, but a mixture of 2 parts of whale oil with 1 part of boiled linseed oil gives good results, and has not such an offensive odor. There are also several good core oils on the market which have practically no odor.

Core-boxes: After the shape or design of a dry sand core has been determined by the patternmaker, a mold must be constructed in which the core may be formed. This mold is called a *core-box,* and should always be marked in such a way that it will be kept with the pattern to which it belongs. The making of core-boxes for dry sand cores is an important part of the patternmaker's work. There are two general classes of core-boxes, *viz.,* those that form complete cores and those that form cores partly by means of the core-box and partly by strickling; the latter are called *skeleton* or *frame* core-boxes.

Core Boards: Core boards are used when sweeping up cores with strickles. The outline of the board governs the lengthwise form of the core, while the strickles give it sectional shape. Core boards are used largely for pipe work and where but one or two

castings are to be made. A core made on a board cannot be removed until it is dried, so that the board must be put in the oven along with the core. These boards do not last very long when made of wood, and if they are to be used a number of times, it is preferable to make them of cast iron.

Core Machines: When many cores are to be made of small size and cylindrical in shape, core machines are sometimes used to good advantage. The advantages of core-making machines are that the work is produced more rapidly and uniformly than by hand and no core-boxes are required.

Core-barrel: A core-barrel, generally made from cast iron, is employed in the making of large cores in the foundry. Instead of making the cores solid, loam is applied to the outside of the core-barrel, the barrel being first wound with rope and the loam mixture applied in a comparatively soft state. The barrel is turned during this process so that the core is formed to a circular section at all points by means of a strickle, which may be shaped to form any contour on the surface of round cores.

Core Oven: Ovens used for drying cores in the foundry generally are made large enough so that a truck with a table and shelves for supporting the cores may be wheeled right into the oven. Shelves are sometimes provided on the sides of the oven on which to place the cores.

Corex. An abrasive which is used in the manufacture of wheels for grinding cast iron, unannealed malleable iron, brass, bronze, etc., is known as *corex.* It is produced from coke and sand in the electric furnace.

Cork. Cork is obtained from the outer layer of the bark of an evergreen species of oak, growing in the south of Europe and on the north coast of Africa. Water and many liquids have no deteriorating effect upon cork, and it may be compressed many thousand times without changing its molecular structure. An important application of cork is for cork inserts in friction clutches, owing to the fact that cork has a high coefficient of friction, probably double that of wood or leather on iron. As a rule, the cork, which has previously been boiled and softened, is forced into holes formed in one of the metallic friction surfaces so that it slightly protrudes above the surface. When the clutch is engaged, the cork will engage the opposing friction surface first, but if sufficient pressure is applied to the clutch, the cork is pressed down flush with the metal surface and acts with it in carrying the load. The coefficient of friction with cork-insert surfaces has been found to average about 0.34, while the average coefficient of friction of cast iron on cast iron is about 0.16, and of bronze on cast iron, about 0.14.

Corliss Cylinder-Boring Machines. Corliss engine cylinders are commonly bored on a special type of machine which resembles a regular cylinder boring machine of the horizontal design, excepting that, in addition to the regular boring-bar, it has two boring-bars for boring the ports into which the steam and exhaust valves are inserted. On a machine of typical design, this port boring attachment consists of two columns which are adjustable along parallel beds attached to the sides of the main bed. One of these columns carries two boring-bars, each mounted on a separate saddle. The saddles are adjustable vertically in order to align the boring-bars with the port holes at varying heights and center-to-center distances. The column on the opposite side of the bed is of smaller size, and carries the outboard bearings that steady the port boring-bars.

Corliss Engine. Steam engines of the Corliss type are equipped with Corliss valves. There are four cylindrical valves, —two steam valves at the top and two exhaust valves at the bottom. These valves are given an oscillating movement. The advantages of this type of valve-gear, as compared with a plain slide valve, are that it permits an earlier cut-off and greater range of expansion, a more perfect steam distribution, and a smaller clearance space.

Corol. A rust-preventive preparation which may be sprayed on metal parts or in which the parts may be dipped to prevent corrosion. Can be applied to metal surfaces even when they are damp, as it will displace any water that may be present. Can be easily removed. Used by manufacturers of airplanes to prevent corrosion on metal parts, especially when exposed to dampness and sea air; particularly suitable for metal parts to be exported.

Corona Loss. When the voltage of an overhead transmission system or of conductors in general exceeds a certain critical value, depending upon the spacing and diameter of the wires, there will appear on the surface of the conductors a halo-like glow to which the name "corona" has been given. This is due to the ionization of the air or other gas surrounding the conductors by the electric field and causes an increase in conductivity of the air or gas. Apart from this luminous effect, the appearance of the corona is accompanied by a certain loss of power, proportional to the frequency and the square of the amount by which the potential difference between the conductors exceeds a certain value known as the "disruptive critical voltage." The action of corona on insulation manifests itself chemically, mechanically, or by heat. At high altitudes particularly it is not advisable to use the smaller sizes of wire for high voltage transmission of power because of this corona loss.

Corowalt. Corowalt is a special corundum abrasive that is adapted for grinding hardened low- or high-carbon steel. Corowalt is produced in the electric furnace in a manner similar to that of alundum.

Corrosion. The forming of an oxide on the surface of a metal; specifically, the forming of rust (iron oxide) on the surface of iron and steel.

Corrosion-resistant Steels. Many different terms and trade names have been applied to corrosion-resistant steels. "Stainless Steel" is a term commonly used to indicate any or all rustless steels or iron alloys designed to resist atmospheric corrosion, the attack of hot or cold acids, and scaling at elevated temperatures. However, "Stainless Steel" is strictly a trade name, originally applied to cutlery steels containing no more than 0.70 per cent carbon and from 9 to 16 per cent chromium which were patented in 1916 by the English metallurgist Brearley, and the genuine "Stainless Steel" produced in this country is a straight chrome-iron alloy made under patents owned by the American Stainless Steel Co., Pittsburgh, Pa.

Application: The applications of stainless steels may be divided broadly into two groups: (1) Where corrosion resistance is required, including resistance to high-temperature oxidation; (2) where unusual mechanical properties of hardness, strength, toughness or ductility are required, including resistance to wear and abrasion. Corrosion-resistant steels cover a wide range of compositions and physical properties. The common applications include cutlery; surgical and dental instruments; poppet valves for internal-combustion engines; turbine blades; pump shafts; architectural trim; polished parts of automobiles; chemical, dairy, laundry, and oil equipment, etc. The chromium content commonly ranges from 10 or 12 to 18 or 20 per cent, some steels having less and some more than these minimum or maximum values. The "18-8" stainless steel often referred to is a steel having about 18 per cent chromium and 8 per cent nickel. The carbon in stainless steels may vary from 0.10 up to 1.00 per cent or more. The higher carbon contents are used for high-grade cutlery, such as pocket-knives, and also for ball-bearing races, balls, valve-seats, bearing surfaces, etc.

S.A.E. 30905 and 30915: These are the standard so-called 18-8 chromium-nickel stainless steels and are suitable for heat resistance up to 1500 degrees F. They may be forged readily, riveted, welded, and are suitable for cold working and deep drawing, but they do not respond to hardening treatment. These steels are quite tough and stringy, and are somewhat difficult to machine. The tensile strength ranges from 90,000 to 100,000 pounds

per square inch in the annealed state. The elongation varies from 60 to 70 per cent. Cold-working will increase the tensile strength to from 120,000 to 125,000 pounds per square inch.

S.A.E. 51210: This grade of stainless steel is used for strip, rod and wire, shafting, forging, tubing, nuts, rivets, screening, and other purposes where a corrosion-resisting steel is required. It can be hammered readily, forged, cold worked and welded and it can be machined at reduced speeds. This grade resists oxidation up to 1200 degrees F.

Stainless Steel with Free Machining Qualities: The high-chromium stainless steel alloys first produced were extremely difficult to machine, and grinding and polishing operations were also difficult and expensive. By producing this steel with a high sulphur content or by the addition of selenium, free machining qualities can be obtained. Such stainless steels contain approximately 0.10 per cent carbon, 18 per cent chromium, 8 per cent nickel, and 0.30 per cent sulphur (or 0.25 per cent selenium instead of sulphur). They can be machined in automatic screw machines with regular tools at speeds equal to, or closely approximating, those used for ordinary Bessemer screw stock. These materials can also be easily drilled, tapped, and threaded with dies. Wire and tubing can be cold-drawn by simply using the lime coat and lubricants regularly employed for drawing ordinary steel.

S.A.E. X51410: This is the free-machining high-sulphur variant of No. 51510. In addition to the high sulphur, this free-machining type contains other elements, such as zirconium, selenium, molybdenum, and copper. This steel is applicable for the same purposes as the other similar types but may easily be machined at standard feeds and speeds used for ordinary steel. It may also be more readily polished. This steel may be hardened up to 300 Brinell, but does not respond as readily to heat-treatment as No. 51210. It resists oxidation up to 1200 degrees F.

Cutlery Grade—S.A.E. 51335: This is the standard cutlery grade of stainless steel and is used solely in the hardened condition. It may be heat-treated to C50 minimum, Rockwell hardness. Only when hardened does it have stainless properties; hence, is not recommended for use in the annealed state. This steel should not be forged over 2000 or less than 1600 degrees F. It has air-hardening properties and must be annealed after forging if subsequent machining operations are to be performed. This steel is used for shafts, bushings, valves and bearings subject to corrosive influences. It will resist tarnishing from vegetable and mineral oil, moist air, water, steam and alkalies, but will not resist hydrochloric, sulphurous, or hydrofluoric acid.

S.A.E. 51510: This grade, although used for the same purposes as No. 51210, is of slightly higher chromium content and is,

therefore, recommended for use only in the annealed condition. This steel can be forged, cold worked and welded, but is not a good machining type. It is somewhat superior to No. 51210 in corrosion resistance. This grade is mostly applied for automobile trim and similar purposes where the maintenance of a bright surface under exposure to oxidizing conditions is essential.

S.A.E. 51710: This grade is used solely for ornamental purposes in sheet and strip, and is not susceptible to heat-treatment except annealing. This steel is more corrosion resistant than the foregoing steels.

Corrugated Flanges. The plain face corrugated type of joint for pipe flanges is a plain face straight flange upon which concentric curves have been cut with a round-nosed tool. On some types of installations, a face of this kind is necessary, as the corrugations have a tendency to prevent the gaskets from blowing out, particularly when the flow in the pipe line is of a nature that requires the use of exceptionally thick gaskets.

Plain Face Scored Joints: This type of joint is made by using a plain straight flange with scores upon the face consisting of concentric rings made with a diamond-pointed tool. On oil or acid lines, where the gaskets must be of lead, a joint of this kind gives the best satisfaction, as the lead gasket squeezes into the scores and assists in maintaining a tight joint, without any undue strain on the bolts and flanges.

Corubin. Corubin is an artificial corundum obtained from the slag produced by the Goldschmidt thermit welding process. It is much purer than the natural corundum and will resist sudden and great changes of temperature without breaking. Chemical vessels made of fireclay and corubin may be heated red-hot and plunged into cold water without breaking, or even showing any tendency to crack.

Corundum. Corundum is an aluminum oxide which is found in nature as crystals which are usually rough and rounded, or massive, with nearly rectangular partings. There are many varieties of corundum, the finely-colored transparent varieties including such gem-stones as the ruby and sapphire, while the impure-granular, and massive forms are known as *emery.* The term "corundum" is often restricted to the remaining kinds; that is, those crystallized and crystalline varieties which are not sufficiently transparent and brilliant for ornamental purposes and which were known to the older mineralogists as "imperfect" corundum. Corundum is superior to emery as an abrasive, because the impurities found in emery are almost entirely absent in corundum; the latter also contains a much larger percentage of crystalline

alumina, which is the element in both abrasives that possesses cutting qualities.

The percentage of crystalline alumina found in corundum obtained from the different sections is approximately as follows: Canadian corundum, from 90 to 95 per cent; Georgia corundum, 77 per cent; Brazilian corundum, 76 per cent; India corundum, 73 per cent. In Canadian corundum, iron oxide, which is the most objectionable impurity in emery, is as low as 1¼ per cent, as compared with 25 per cent in Naxos emery. Corundum is harder than emery, and, therefore, the abrasive grains will remain sharp longer. The Canadian corundum is mined in Eastern Ontario, where there are very large and practically inexhaustible deposits. The corundum occurs in hexagonal crystals imbedded in felspar, syenite, chlorite, and occasionally in some other nonmetallic minerals or gangues. Only the crystals are used, all of the felspar and other gangues being removed by crushing the material and passing it over concentrating jigs and tables, and over magnets and blowers.

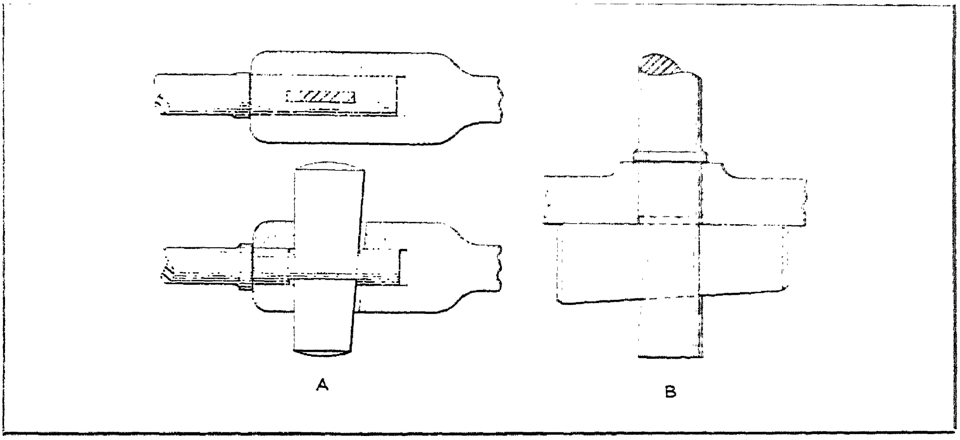
Cosecant of Angle. See Functions of Angles.

Cosine of Angle. See Functions of Angles; also Law of Sines and Cosines.

Coslettizing. Coslettizing is a process for rust-proofing iron and steel. A solution is made from one quart of concentrated phosphoric acid, one quart of water, and one pound of iron filings. This mixture is allowed to stand until the iron is entirely dissolved, and then it is added to water in the proportions of one part of solution to 50 parts of water. The work to be treated is first cleaned as for plating, either by scratch-brushing or by immersion in a muriatic-acid dip, in order to remove any rust that may be present. The parts are suspended in the solution by means of iron wire or hooks, or, in the case of small articles, by placing in iron or earthenware baskets. The solution must be kept close to the boiling point, and the articles are allowed to remain in it for from ½ to 3 hours, depending upon the nature of the work, a heavy coating being produced in from 2 to 3 hours time. A convenient arrangement for the bath is to make up the solution in an enamel or agateware tank, and heat this tank by placing it in boiling water. After the articles are removed from the solution, they should be allowed to dry in the air, and may then be scratch-brushed on a fine wire wheel, revolving at 600 revolutions per minute, and oiled with linseed or paraffin oil. Another solution is composed of 6 ounces of zinc, 1 pint of phosphoric acid, and 1 pint of water, making a stock solution which is diluted by using 1 ounce of stock solution per gallon of water. The treatment of the work is the same as for the other solution.

Cotangent of Angle. See Functions of Angles.

Cotter. A cotter is a form of key that is used to connect rods, etc., that are subjected either to tension or compression or both. Diagram *A* shows how a cotter is used to hold the valve-stem and valve-rod of an engine together. The cotter is of rectangular section and the edges may be either square or rounded, the latter form being generally used. It is driven transversely through the two members to be held together and the slots are offset somewhat so that the cotter forces the inner rod (in this particular case) against its shoulder. Frequently, a taper fit is employed instead of a cylindrical fit and shoulder, in which case the rod is drawn tightly into the taper hole. In some cases, a cotter simply passes through the end of a rod as shown at *B*.



Two Methods of Applying Cotters

Cotter Files. These files are made in both taper and blunt forms, and from pillar sections. They are double-cut, mostly bastard, and principally used for filing the grooves for cotters, keys, etc.

Cotter-Pins. The cotter-pin or split pin is used to prevent pins and other parts from working out of their holes, and nuts from unscrewing. After the pin is inserted through a small hole in the part to be kept in place, the ends are spread apart. The nominal "trade diameter" is the diameter of the pin before the sections are divided or expanded. The S.A.E. Standard diameters are 1/16, 3/32, 1/8, 5/32, 3/16, 7/32, 1/4 and 5/16 inch. The lengths under the head vary from 5/16 inch for the 1/16-inch size up to 3 inches for the 7/32 to 5/16-inch sizes.

Cotton Gin. The cotton gin was invented by Eli Whitney in 1792. This is one of the few great inventions which is due

entirely to the work of one man. As the great importance of this invention was generally recognized, many came to see the machine even before patent rights had been granted. The privilege of inspection was denied in order to safeguard the invention, but the building was broken into at night and the machine removed; consequently, its construction was no longer a secret and before Whitney could secure a patent, a number of machines were in successful operation which deviated only slightly from the original design. The result was that Whitney had considerable trouble later in establishing rights to the invention.

Coulomb. A coulomb is the quantity of electricity transmitted by a current of one ampere in one second. It is also equal to the quantity of electricity contained in a condenser with a capacity of one farad, when the same is subject to an electromotive force of one volt. One ampere-hour is equal to 3600 coulombs. The International Electrical Congress, held in Chicago in 1893, recommended the adoption of the coulomb as the unit of quantity of electricity, and, by Act of Congress, July 12, 1894, this has been made the legal unit in the United States.

Counterboring. This operation is for the purpose of enlarging some part of a cylindrical bore or hole. For example, if a machine screw hole is enlarged at one end to receive a fillister-head screw, this is counterboring and the tool used is known as a *counterbore*. Counterboring is also done in connection with lathe and boring-mill work, as, for example, when the bore of a cylinder is enlarged at the ends to form a clearance space or counterbore, as it is called.

Counterboring Tool. The tool known as a counterbore is used for enlarging previously drilled holes in such a manner that the bottom of the enlarged hole has a square shoulder. The tool consists of a body part, the end of which is provided with cutting edges, a guide or "pilot" which accurately fits the hole already drilled, and a straight or taper shank by which the counterbore is held and driven.

Counter Cells. Counter cells are used for reducing the charging voltage when charging storage batteries. These cells have two electrodes of pure lead without any active material, but the electrolyte. They give practically constant potentials for all currents passing through them, but no power. The positive electrode of a counter cell is connected to the positive pole of the main cell, so that the potential of the counter cell opposes that of the main cell.

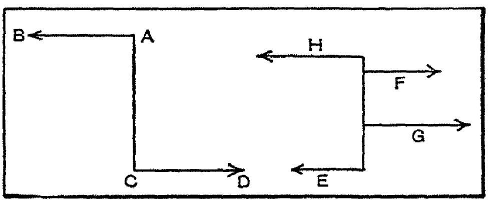
Counter-Electromotive Force. The counter-electromotive force is the voltage which opposes the flow of current through a

conductor whenever that conductor is moving through an opposing electromagnetic field. Thus, there are two sources of electromotive force in the windings of a motor that is running: (1) The voltage which is impressed on the armature or rotor from an outside source; (2) the voltage which is set up by the armature or rotor windings in cutting the lines of force or magnetic flux set up by the field. These electromotive forces are opposite in direction, and the latter is called the counter-electromotive force, because it opposes the electromotive force impressed across the armature to cause it to turn as a motor. The current that flows is proportional to the difference between the two voltages.

Countershafts. A countershaft is a short shaft which is driven from a main shaft and serves either to start or stop a machine independently of other machines which may be driven from the same main shaft. With the usual arrangement, the countershaft is driven by a belt and transmits motion to the driven machine by another belt. There are several types of countershafts, some of which are arranged for reversing the direction of rotation, whereas others provide two or more speed changes.

Countersinking. On some classes of work, screws having heads that are conical on the under side are used. Forming a conical seat for a head of this shape is known as *countersinking*. The operation is similar to counterboring, except that a tool for forming a conical seat has cutting edges which incline to suit the required angle. The pilot form of countersink is used after the hole for the screw-body has been drilled. Countersinks are also used which have a drill of the proper size at the end, instead of a pilot, so that the straight and conical parts of the hole are finished in one operation.

Counting Board. A tray provided with a large number of semi-spherical depressions, usually 1000, which is employed for the counting of steel balls. By filling the tray with balls until one ball rests in every depression, the counting of balls in great quantities is easily done, one operator being able to count as many as a million balls a day.



Couples of Forces

Couples of Forces. If the forces *AB* and *CD* (see illustration) are equal and parallel, but act in opposite directions, then the resultant equals 0, or in other words, the two forces have no resultant and are called a *couple*. A couple tends to produce rota-

tion. The measure of this tendency is called the *moment of the couple,* and is the product of one of the forces multiplied by the distance between the two. As a couple has no resultant, no single force can balance it, or counteract the tendency of the couple to produce rotation. To prevent the rotation of a body acted upon by a couple, two other forces are, therefore, required, forming a second couple. The moment of this couple must be equal to the moment of the couple which it balances. In the illustration, *E* and *F* form one couple and *G* and *H* are the balancing couple. The body on which they act is in equilibrium if the moments of the two couples are equal and tend to rotate the body in opposite directions.

Couplings of Electric Type. In couplings of this type, the driving and driven members are not connected mechanically. For example, the Diesel engines of a motorship equipped with this type of coupling have no mechanical connections between them and the gears that turn the propeller. Power is transmitted from the engines to the gears through these couplings which provide an electric cushion, as the power is transmitted electrically across the air gaps of the couplings. They prevent the pulsations of engine torque from reaching the gears, and also enable the engine to be connected to the propeller instantly.

A coupling consists of two rotating members, revolving one inside the other. One is mounted rigidly on the engine shaft, and the other is connected to the gear. The external member has salient field poles, connected to the ship's direct-current auxiliary power supply for excitation. Rotating inside this field is the inner member with a squirrel-cage winding. The mechanical rotation of the field member creates a rotating magnetic field which induces currents in the squirrel cage. The interaction of the resulting magnetic fields creates powerful forces which cause the squirrel cage to follow the field except for a small slip, just as the secondary of a squirrel-cage induction motor follows the rotating magnetic field set up by the stator. The efficiency of these couplings is 97.5 per cent approximately.

Couplings of Fluid Type. Couplings of the fluid or hydraulic type are now being used both in automobile transmissions and for certain industrial applications. With couplings of this general type, the motion of the driving member is transmitted to the driven member through the medium of an oil fluid rather than by direct physical contact. The effectiveness of the fluid coupling depends upon this feature, which, in the case of automobile transmissions, for example, permits a gradual shockless acceleration of the driven part up to the point where its speed is nearly the same as that of the driver. The operation of all cou-

plings of this type is due to the action of centrifugal force upon the fluid, in conjunction with the design of the driving and driven members. Just how it is possible to transmit not only motion but considerable power through an oil fluid, and without direct contact between driving and driven members, will be explained in connection with the particular design of fluid coupling used in the Oldsmobile transmission.

Fluid Coupling in Oldsmobile Transmission: The fluid coupling is an important feature in the Hydra-Matic drive of the Oldsmobile cars. While this coupling operates in conjunction with a fully automatic four-speed transmission, the coupling only will be described. The general arrangement of this coupling is illustrated by the diagram. An impeller *A* and a runner *B* are enclosed in a housing containing an oil fluid selected to function

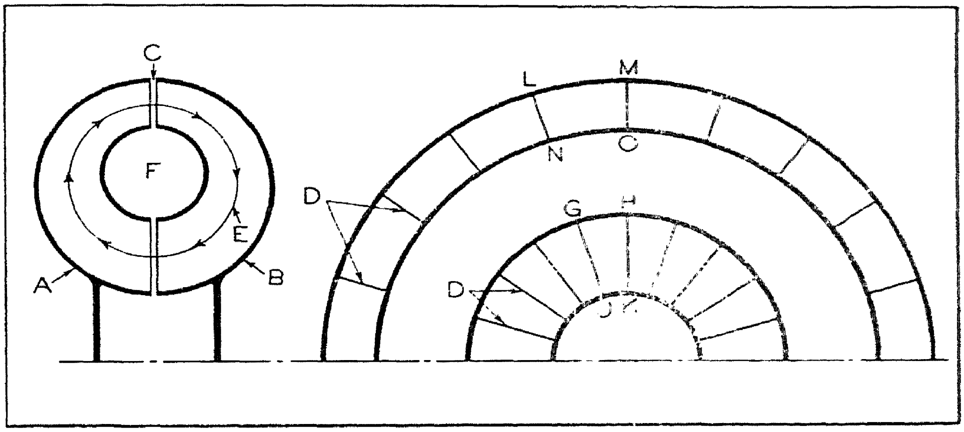


Diagram Illustrating General Arrangement of a Fluid Coupling

under a wider range of temperatures than are likely to be encountered. The impeller is driven by the engine (through a planetary gear set which, when in reduction, brings the impeller speed down to about 0.7 times the engine speed), and the runner transmits motion to the rear wheels through the automatic transmission and propeller shaft.

The impeller and runner form an annular channel of circular cross-section, with a small clearance space *C* between these two members. The semicircular channels in both impeller and runner are divided into cells by a number of radial partitions or vanes *D*, as shown by that part of the diagram representing a side view. When the coupling is operating, these cells are filled with the oil fluid which is continually circulated from the transmission housing to the coupling and back, thus preventing any local heating or excessive rise in temperature.

How the Coupling Fluid Transmits Motion: When the engine is started and impeller *A* begins to rotate, the fluid within the various cells of the impeller's semicircular channel also receives a circular motion around the coupling axis. At the same time, the fluid in each cell begins to rotate around the cell itself along paths *E*, as indicated by the arrows. The power, which can be transmitted from impeller *A* to runner *B*, depends upon the rate of this transverse rotation. But why does the fluid have such rotation and what causes the runner to be driven by the impeller?

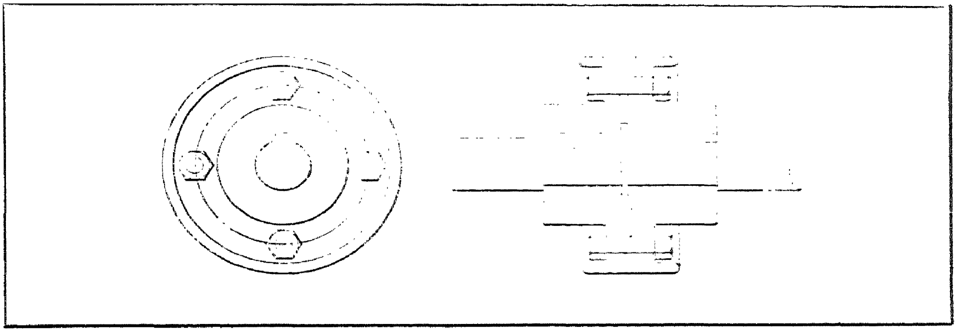
The transverse rotation *E* is due to the unbalance between the centrifugal force of the liquid in the driving member *A* and the driven part *B*. This unbalance is due to the slower speed of B, especially during the starting period. As the speed of impeller *A* increases, runner *B* is gradually accelerated until finally it operates at practically the same speed as the driving member, except for a slight lag or slip which is said to be less than 1 per cent under the ordinary range of driving conditions. As the speeds of the driving and driven members approach each other, this centrifugal unbalance is reduced, and, consequently, the rate of transverse rotation or circulation of the fluid decreases. This is accompanied by a reduction in the torque-transmitting capacity of the coupling, but the car is now up to normal operating speed and the coupling has less work to do.

When the transmission gears are shifted to the third- and fourth-speed positions (which, like all shifting, is done automatically), the coupling transmits only about 40 per cent of its full torque capacity. When the impeller and runner are rotating together we have, then, an annular body of fluid rotating both around the coupling axis and transversely in a number of cells. This whirling mass of fluid has, of course, considerable momentum, and the two sections of the coupling are connected by this fluid body through which practically all of the energy in the driving part is transmitted to the driven member.

Incidentally, it will be noted that the central space *F*, forming a vortex around which the transverse rotation occurs, is located eccentrically relative to the annular ring formed by the two semicircular parts. This eccentric location of the vortex is for obtaining equal areas at all points in the cells. For example, the area of the opening GHJK at the inner part of the cell, where the circumferential width is less, is equal to the area LMNO at the outer part, where the circumferential width is greater, thus making it necessary to reduce the radial width.

What Happens when the Engine is Idling? When the foot is off the accelerator and the engine is idling, no motion is transmitted by the impeller to the runner. Why is this so in view of the fact that the impeller is still rotating?

It is evident, from the preceding description, that the operation of the coupling depends fundamentally upon centrifugal force which varies according to the *square* of the velocity in feet per second. Now, when the engine is idling, the transmission is in first gear and then the impeller turns at about 0.7 times the crankshaft speed. Since the square of 0.7 (representing impeller speed) is about ½ of the square of 1 (representing the crankshaft speed), the torque under these conditions is insufficient to start the runner and overcome the resistance of the car to motion or even to slight creeping movements. When the accelerator is pressed down and the engine speed increases, the whirling body of fluid at first impinges against the vanes of the stationary runner which, at once, begins to rotate and at an increasing rate until, finally, its vanes, like those of the impeller, are embedded in a rotating fluid body which offers high resistance to any lagging of the driven member. The entire action of the coupling



Flange Coupling

through the accelerating period is such that motion is transmitted rapidly but smoothly through the flexible fluid medium.

Couplings, Pipe. Couplings are threaded internally for receiving the ends of pipes. They are threaded either with right-hand or with right- and left-hand threads the same as nipples. "Wrought couplings" are commonly used for "wrought pipe."

Couplings, Shaft. A shaft coupling is a device for fastening together the ends of two shafts, so that the rotary motion of one causes rotary motion of the other. One of the most simple and common forms of coupling is the flange coupling (see illustration). It consists of two flanged sleeves or hubs, each of which is keyed to the end of one of the two shafts to be connected. The sleeves are held together and prevented from rotating relative to each other by bolts through the flanges as indicated. See Flexible Couplings.

Cowles Process. A method for producing aluminum alloys directly from the aluminum ore. This process was used in the early days when aluminum was very expensive, and when commercial alloys could not be produced by using the pure metal. Later, it became the practice to alloy aluminum as a metal with other metals, but there has been a resumption of the direct production of aluminum alloys from the ore. The process consists mainly in mixing bauxite with carbon and the metal to be alloyed, and heating the mixture in an electric furnace. In the presence of the carbon, the aluminum oxide is reduced to aluminum, and this alloys directly with the other metal contained in the furnace. Alloys containing as high as 30 per cent of aluminum have been produced in this manner.

Cowper-Coles Process. The process known by this name is a galvanizing process used for covering iron and steel with metallic zinc. The process is generally known as *sherardizing* from its inventor, Mr. Sherard Cowper-Coles. The principle of the process is explained under the heading Sherardizing.

Crab. In an overhead traveling crane, the crab is the carriage moving crosswise of the span along the bridge or girder. It is from this that the load is suspended.

Cracking Process. The cracking process consists practically in distilling oils at a higher temperature than the normal boiling point. This process, as applied in producing gasoline, may also be defined as a method of splitting up the molecular structure of hydrocarbon molecules by the application of heat supplemented, ordinarily, by pressure which, in modern processes, may be several hundred pounds to the square inch. There are various modifications of the cracking process. These developments have made it possible to secure large amounts of gasoline from the heavy oils, so that the volume of light crude oil is no longer a true indication of the potential gasoline supply. According to a prominent authority, properly cracked gasolines as compared with "straight-run gasoline" obtained from a crude still, have the following advantages: (1) Generally a higher percentage of the lighter and more volatile factions; (2) better starting qualities as applied to internal combustion engines; and (3) non-detonating or "anti-knock" qualities.

When petroleum or crude oil is subjected to ordinary distillation by the application of heat, the lighter products, such as gasoline and kerosene, are distilled off to a temperature of about 300 degrees C. (572 degrees F.). For higher temperatures the hydrocarbons decompose partially so that some light products are produced and distilled along with the heavier products. If the temperature is increased sufficiently, the entire oil residue may

be distilled, leaving only a variable amount of residual carbon. This property of all heavy petroleums, which results in decomposing into hydrocarbons of lower molecular weight by heating, is generally known as cracking. There are various cracking processes, such as (1) cracking in the vapor phase under *(a)* atmospheric pressure or under *(b)* high pressures of several hundred pounds to the square inch; (2) cracking in the liquid phase *(a)* with distillation either at atmospheric pressure or under high pressure, or *(b)* without distillation and with high pressure. As to the origin of the cracking process, a United States patent was granted in 1860 to Luther Atwood for the production of light hydrocarbon illuminating oils from heavy oils, paraffins, etc. The first record of pressure distillation appears to be in an English patent granted to James Young in 1865. The extremely high pressure process is covered by a United States patent granted to Benton in 1886. This patent deals with temperatures ranging from 700 to 1000 degrees F. and pressures as high as 500 pounds per square inch.

Cranes. Cranes may be classified in a number of ways, according to the principal characteristic considered.

Rotary Cranes: Rotary cranes may be divided into two main subdivisions: *jib* and *pillar* cranes. The *jib crane* consists mainly of a post or pillar from which extends a horizontal arm or jib. On this jib, a crab or trolley moves in a radial direction. *Pillar cranes* are provided with a pivot at the lower end of the column or post only, and are supported entirely from the foundation. These cranes, as a rule, are not provided with a jib and trolley, and, hence, the load is rotated in a horizontal direction along the periphery of a circle, but has no radial movement. A special type known as *pillar jib crane* is identical with the regular type of pillar crane in that it is pivoted and supported entirely at the foundation, but is provided with a jib on which a trolley moves, so that the load can be moved both in a radial and circular direction. Pillar cranes having a rotary motion only, but no trolley motion, are frequently known as *swing cranes.* The same name is applied to jib cranes if they are not provided with a trolley motion. Pillar cranes which are mounted on wheels, and so arranged that they can travel longitudinally upon rails, are known as *portable cranes* or *walking cranes.* When these portable cranes are provided with a steam engine capable of propelling them along the rails, they are known as *locomotive cranes.* In this type, steam power is also used for hoisting and moving the load.

Rectilinear Cranes: The most common of all rectilinear cranes is the *overhead traveling crane* in which there is, in addition to the lifting motion, provision for two horizontal movements at right angles to one another, so that the load can be deposited at

any point within the rectangle covered by the movement of the crane. Traveling cranes consist of a bridge, generally spanning the bay of a shop or foundry, which moves longitudinally on overhead tracks provided at the end of the bridge, giving the straight-line motion in one direction. On this bridge is mounted a trolley or crab which moves transversely along the bridge, thus giving the straight-line motion in the other direction. A *gantry crane* is similar to the overhead traveling crane except that the overhead bridge is here carried at each end by a trestle which travels on longitudinal tracks on the ground. A trolley is placed on the bridge to give the transverse motion. *Bridge cranes* have a horizontal straight-line movement in one direction only, the bridge being in a fixed position, while a trolley moves along the bridge. *Tram cranes* also have a movement in one direction only, except that in this case a very short bridge without a trolley is provided, which travels longitudinally on overhead rails.

Crankshaft Cold Saw. The crankshaft cold saw cutting-off machine is arranged for carrying two saws upon a single arbor so that two cuts may be made simultaneously when sawing out the web of a crank. These machines are built in various designs and may be used for many other operations, such as sawing out the ends of locomotive main-rods of the open-end type, and for similar work.

Crankshaft Grinding. The modern method of finishing crankshaft bearings is by grinding. The bearings may either be rough-turned in a lathe equipped for this purpose, and then be finished by grinding, or they may be ground directly from the rough drop-forging. The practice in different shops varies; ordinarily, whether or not crankshafts are rough-turned prior to grinding depends upon their size and the amount of stock to be removed. One method of finishing the pins is to use a wheel that is equal in width to the width of the bearing, so that the entire pin can be finished by feeding the wheel straight in, and without a traversing movement. Grinding machines which are used exclusively for grinding crankshafts of the type used in motors for automobiles, launches, etc., are equipped with special work-holding fixtures so arranged that the different crankpins may be aligned with the axis of the grinding machine spindle.

Creosoting Processes. Different methods are used for applying creosotes or other preservatives to wood poles. In the closed-tank method, the poles are placed in a large tank and steamed for from five to eight hours; a partial vacuum is then applied, after which the creosote is run in at a temperature of from 140 to 175 degrees F. under sufficient pressure to obtain the amount of absorption desired. In the open-tank creosoting

process, usually applied to the butts of poles only, the poles are placed in an inclined or vertical position with the butts immersed in the creosote, which is kept at a temperature of about 220 degrees F., for about six hours. The bath is then allowed to cool, and after it has fallen to 110 degrees F., the poles may be removed; or the poles may be changed to a cold bath (110 to 150 degrees F.) and allowed to remain for several hours. During the period of the warm bath, the air and moisture in the cells of the wood are driven out, and during the period of cooling off, the creosote enters the cells and remains there. By the open-tank method it is not possible to impregnate the wood to the same depth as with the closed-tank or pressure method. The treatment is, however, worth while, and the United States Forest Service estimates the useful life to be approximately twenty years for chestnut and western cedar, twenty-two years for northern white cedar, and twenty years for pine in the dry climate of western United States. In this connection, it should be mentioned that in poles with treated butts, it is the upper part of the poles that will decay first and govern the life of the pole. In the so-called "brush treatment," the preservative is applied with a brush. This practice is sometimes modified by pouring or spraying the preservative on the poles.

Crest of Thread. The top surface of a screw thread is known as the crest. The American standard thread has a flat crest, and the British or Whitworth standard a rounded crest.

Crest Voltmeter. This is a voltmeter depending for its indications upon the crest, that is, the maximum value of the voltage applied to its terminals.

Critical Speed of Rotating Body. If a body or disk mounted upon a shaft rotates about it, the center of gravity of the body or disk must be at the center of the shaft, if a perfect running balance is to be obtained. In most cases, however, the center of gravity of the disk will be slightly removed from the center of the shaft, owing to the difficulty of perfect balancing. Now, if the shaft and disk be rotated, the centrifugal force generated by the heavier side will be greater than that generated by the lighter side geometrically opposite to it, and the shaft will deflect toward the heavier side, causing the center of the disk to rotate in a small circle. These conditions hold true up to a comparatively high speed; but a point is eventually reached (at several thousand revolutions per minute) when momentarily there will be excessive vibration, and then the parts will run quietly again. The speed at which this occurs is called the *critical speed* of the wheel, and the phenomenon itself is called the *settling* of the wheel. The explanation of the settling is that at this speed

the axis of rotation changes, and the wheel and shaft, instead of rotating about their geometrical center, begin to rotate about an axis through their center of gravity. The shaft itself is then deflected slightly so that for every revolution its geometrical center traces a circle around the center of gravity of the rotating mass.

Critical speeds depend upon the magnitude or location of the load or loads carried by the shaft, the length of the shaft, its diameter and the kind of supporting bearings. The normal operating speed of a machine may or may not be higher than the critical speed. For instance, some steam turbines exceed the critical speed, although they do not run long enough at the critical speed for the vibrations to build up to an excessive amplitude. While a machine may run close to the critical speed, the alignment and play of the bearings, the balance and construction generally, will require extra care, resulting in a more expensive machine; moreover, while such a machine may run smoothly for a considerable time, any looseness or play that may develop later, causing a slight unbalance, will immediately set up excessive vibrations.

Critical Temperatures. The temperatures at which certain changes in the chemical condition of tool steel take place, during both heating and cooling, are referred to as the decalescence and recalescence or critical points, and the effect of these molecular changes is as follows: When a piece of steel is heated, it reaches a certain point at which it continues to absorb heat without appreciably rising in temperature, although its immediate surroundings may be hotter than the steel. This is the *decalescence* point. Similarly, steel cooling slowly from a high heat will, at a certain temperature, actually increase in temperature, although its surroundings may be colder. This takes place at the *recalescence* point. The recalescence point is lower than the decalescence point by anywhere from 85 to 215 degrees F., and the lower of these points does not manifest itself unless the higher one has first been fully passed. These critical points have a direct relation to the hardening of steel. Unless a temperature sufficient to reach the decalescence point is obtained, no hardening action can take place; and unless the steel is cooled suddenly before it reaches the recalescence point, no hardening can take place. The critical points vary for different kinds of steel and must be determined by tests in each case. It is the variation in the critical points that makes it necessary to heat different steels to different temperatures, for hardening.

Crochet File. Crochet files are rounding on both edges and, in a lengthwise direction, taper to a small point.

Crodon. Crodon is a trade name for a chromium plate that is claimed to be ten times as hard as nickel plate and three times as hard as cold-drawn steel. On the hardness scale, it is listed at 9 as compared to the diamond at 10. This hardness is particularly useful where resistance to rubbing action is required.

"Crodon" is not oxidized below 700 degrees F., and will protect steel from scaling at 1500 degrees F. and above. This property is being utilized in pyrometer parts, soot cleaner elements, oil burner parts, oil cracking equipment, and thermostat parts. "Crodon" is not affected by organic acids, salt water atmosphere, nitric acid, or sulphur compounds. This resistance to sulphur has proved useful in rubber molds and on oil equipment in contact with sulphur bearing oils at high temperatures. See Chromium Plating.

Croloy. A carbon-molybdenum steel with thin sheets of chromium stainless-steel welded to it. Can be hot-formed, spun, or welded as easily as unbonded plate. Useful where strength, as well as resistance to corrosion, is required.

Cross. A pipe fitting with four branches arranged in pairs, each pair on one axis, and the axes at right angles. When the outlets are otherwise arranged the fittings are branch pipes or specials.

Cross-Compound Engines. Cross-compound engines consist of two complete engines, except for the shaft and flywheel, which are common to both. The engine is so piped that the high-pressure cylinder exhausts into the low-pressure through a receiver. The use of this type is confined principally to cases where large amounts of power are required and where there is ample floor space, as in rolling mills and similar locations.

Cross-Cut File. A type having one round edge with sides tapered toward the opposite edge. A cross-cut file is single-cut, the same as a mill bastard file of the same size.

Crossing File. Crossing or cross files have a double oval section, one side being shaped like a half-round file and the other like a cabinet file. The cut is either bastard, second-cut, or smooth.

Cross-Over. A small fitting with a double offset, or shaped like the letter U with the ends turned out. It is only made in small sizes and used to pass the flow of one pipe past another when the pipes are in the same plane.

Cross-Section Paper. Cross-section paper has horizontal and vertical ruled lines spaced the same distance apart. When this ruling is so made that the horizontal spaces are much less than the vertical, the paper is properly called *profile paper.* Cross-

section paper is used for making sketches, diagrams, etc., and for free-hand work; the ruling is of great assistance in properly proportioning the parts. It is also largely used in the plotting of graphic charts and similar work. Cross-section paper is obtainable with a ruling of either 10 or 16 lines to the inch, and also with millimeter ruling. There is also cross-section paper made with 8 and 12 lines to the inch.

Cross Valve. (1) A valve fitted on a transverse pipe so as to open communication at will between two parallel lines of piping. This type is much used in connection with oil and water pumping arrangements, especially on board ship. (2) Usually considered as an angle valve with a back outlet in the same plane as the other two openings.

Crotch. A pipe fitting that has the general shape of the letter Y. Caution should be exercised not to confuse the crotch and a Y-fitting or wye.

Crown Gear. In bevel gearing, when the pitch-cone angle of one of the gears is 90 degrees, this gear is called a *crown gear.* In this case, there is, properly speaking, no pitch cone, but rather a pitch plane. The crown gear of bevel gearing is equivalent to the rack of spur gearing.

Crown of Pulley. See Pulley Crown.

Crucible. Crucibles are pots used for melting small amounts of various metals. Their principal use in the iron and steel industry is in the manufacture of crucible or tool steel, when they generally have a capacity of from 75 to 200 pounds. Electric furnaces, however, are now used extensively for producing tool steel. The most extensive use for crucibles is in the brass industries. In many English and some American plants, the crucibles are made of a high quality of clay mixed with about 5 per cent of powdered coke. They are then known as *clay crucibles* or "white pots," but the care required in the handling of these crucibles has brought them into disfavor with most American manufacturers, who use graphite crucibles instead. Graphite crucibles can be recharged while cold, tested for thickness and cracks before each charging, and will stand rougher handling and more heats than the clay pots.

Crucible Furnace. A crucible furnace is one in which metal that is to be melted is contained in crucibles placed in the furnace. The furnace may be heated by coal, coke, gas, or oil. The use of gas or oil lessens the labor required and permits better control of the heat; it also permits heat to be localized, when desired; but carelessness in handling these fuels is more likely to destroy the crucibles than in the case of coal or coke.

Crucible Steel. Crucible Steel, also known as *tool steel, high-carbon steel,* and, in England, sometimes as *pot steel,* is made by using high-grade, low-phosphorus wrought iron and adding carbon to it. The name *crucible steel* is derived from the fact that in the final process of making this steel, it is melted in crucibles. Small pieces of wrought iron are put directly into an air-tight crucible containing the proper amount of powdered charcoal, and melted down. In this way, the proper amount of carbon is added in order to form the high-carbon steel desired. The process was first developed by Robert Huntsman, in England, about 1740. Wrought-iron is always used in the making of crucible steel of the best grade; but cheaper grades of steel are sometimes made by using Bessemer and open-hearth soft steels; this product, however, is not as good as when wrought iron is used.

Crude Oil. See Petroleum.

Crystallography. See Metallography.

Crystolon. The trade name "Crystolon" is used by the Norton Company for silicon carbide, as well as for various products made of silicon carbide. See Silicon Carbide.

Cubic Equation. See Equations.

Cubic Measure. 1 cubic yard = 27 cubic feet; 1 cubic foot = 1728 cubic inches; the following measures are also used for wood and masonry; 1 cord of wood = $4 \times 4 \times 8$ feet = 128 cubic feet; 1 perch of masonry = $16\frac{1}{2} \times 1\frac{1}{2} \times 1$ foot = $24\frac{3}{4}$ cubic feet.

Cuferco. This material has an electrical conductivity about 70 per cent that of copper, and a tensile strength about equal to hot-rolled, low-carbon machinery steel. It has a tensile endurance limit 23 per cent higher than that of Cupaloy. Particularly suitable for tips for spot welders, since it can be hardened by heat-treating and is softened very little by repeated applications of heat.

Culm Coal. Finely pulverized coal which passes through a screen of 3/16-inch mesh. It is often used for power plant purposes. Culm coal is also known simply as *culm,* and also as *slack of screenings.*

Cupalloy. Copper-base alloy, the electrical conductivity of which approaches that of pure copper, although the alloy is much harder than pure copper and has much greater strength. Suitable for commutators, slip rings, and other parts of electrical equipment.

Cupaloy. An alloy that can be obtained with elastic strength of 35,000 pounds per square inch and with remarkable heat and electrical conductivity characteristics. Withstands temperatures of 750 degrees F. with relatively little permanent softening. Rate of wear under severe tests is only 40 per cent of that of hard-drawn copper. Used in making continuous welds that are unusually strong and gas-tight, as in welding streamline trains, cooling systems for electric refrigerators, etc. When used for welding tips, the alloy has a service life several times longer than that of pure copper, and from 50 to 200 per cent longer than that of other low-resistance alloys.

Cupola Bessemer Electric Process. One method of producing the "white iron" used in making malleable castings is known as the "cupola Bessemer electric process." Briefly, the iron is melted in the ordinary cupola, blown in a Bessemer converter to obtain the proper analysis, and reheated in an electric furnace preparatory to casting. This system can be used to advantage in large plants having a central melting room. The grade of malleable iron produced is excellent.

Cupola Jack Polishing Machine. A type of polishing machine known as the "cupola jack," has been extensively used, especially in the cutlery industry. The cupola jack frame consists of a cast-iron base with two cast-iron upright columns, connected by a brace at the middle. The upper end of each column is arranged to hold a removable hard-wood block in a horizontal position, with the end of the grain against the end of the shaft, and fastened in place by a set-screw. The spindle and arbor hole of the wheel are both tapered, and the polishing wheel is driven on the spindle with a tight fit. The ends of the spindle are tapered down to points, and fitted into countersunk depressions cut into the ends of the hard-wood blocks which constitute the bearings.

Cupolas and Air Furnaces. Two kinds of furnaces are used for melting iron preparatory to making castings, namely, cupola furnaces or "cupolas," as they are commonly called, and reverberatory or air furnaces. The cupola furnace is the most common, and is more simple in operation. In this kind of furnace, the iron and the fuel are charged together, while, in the air furnace, they are charged in separate compartments. The latter type of furnace is more frequently used in the making of malleable-iron castings. The cupola type of furnace is used in nearly all cases except when it is necessary to melt large bodies of iron, or when very large castings are to be made; the reverberatory type is preferable in the latter case, because a large body of metal can be obtained at one tapping. Ordinarily, some flux, such as limestone, is placed in the cupola when charging. This flux melts and serves the

double function of first forming a slag by the combination of the lime with the silica from the charge, thus removing the silica, and also forming a protective covering for the bath of molten metal in the well of the cupola. In determining upon the various mixtures for producing different kinds of iron in a cupola, it is necessary to consider the quality and quantity of pig iron and scrap iron of various kinds, as well as the fuel and the flux that may be used.

Cupro-Nickel. Cupro-nickel is an alloy which consists of from 79 to 81 per cent of copper, the remainder being nickel, with a permissible iron content not to exceed 0.75 per cent.

Curling and Wiring Dies. Curling and wiring dies are used extensively for curling over or "wiring" the edges of pails, pans, and many other similar articles made of tinware, brass, copper, etc. What are known as *curling dies* are also used, to some extent, for rolling small tubular parts or forming cylindrical edges on hinges, etc. The dies used in conjunction with tinware are commonly called *wiring dies,* because of their use for curling the edges of circular shaped articles around a wire, thus forming a strong, smooth edge. In many cases, the edges are curled without inserting a wire; this operation is usually referred to as "false" or "imitation" wiring, and these dies are also known as wiring dies. Curling or wiring dies for tapering parts such as milk pans, etc., have a punch which is composed of six or eight segments instead of being solid, so that it can contract when entering the tapered part.

Currency Coining Pressures. See Coining Pressures.

Custer Process. A method of producing castings in permanent molds. See Castings in Permanent Molds.

Cut-Off. The cut-off is the point in the stroke of a steam engine at which the admission valve closes the port and the expansion of steam begins.

Cutter Grinder. Cutter grinding is often done on cylindrical grinding machines of the universal type, and even in the lathe, by the use of a grinding attachment, especially in small shops, but it is preferable to use a machine designed especially for this class of work. These special machines are so arranged that they may be used for grinding plain cylindrical cutters, angular cutters, end-mills, side-mills, formed cutters, reamers, circular forming tools, saws for cutting-off machines, and a variety of other tools. While the universal tool- and cutter-grinders made by different manufacturers vary more or less as to details, they are similar in their general arrangement and operate on the same general principle.

Tooth-rest for Cutter Grinding: A tooth-rest is used to support a cutter while grinding the teeth. For grinding a cylindrical cutter having helical or "spiral" teeth, the tooth-rest must remain in a fixed position relative to the grinding wheel. The tooth being ground will then slide over the tooth-rest, thus causing the cutter to turn as it moves longitudinally, so that the edge of the helical tooth is ground to a uniform distance from the center, throughout its length. For grinding a straight-fluted cutter, it is also preferable to have the tooth-rest in a fixed position relative to the wheel, unless the cutter is quite narrow, because any warping of the cutter in hardening will result in inaccurate grinding, if the tooth-rest moves with the work. The tooth-rest should be placed as close to the cutting edge of the cutter as is practicable, and bear against the *face* of the tooth being ground.

"Cutting Down." When parts are finished by buffing the term "cutting down" is applied to the operation of removing slight imperfections left either by previous polishing or by rolling, stamping, etc. The relatively high finish obtained by cutting down is refined by "coloring" which gives a high luster either preparatory to plating or on surfaces after plating.

Cutting Metals with Oxidizing Flame. The principle of metal cutting by using an oxy-acetylene or other gas-burning torch, is based on the fact that, if a piece of steel or iron is brought to a red heat and a jet of pure oxygen is turned against it, the metal will be oxidized or will burn. The ordinary cutting torch consists of a heating jet using oxygen and acetylene, oxygen and hydrogen, or, in fact, any other gas which, when combined with oxygen, will produce sufficient heat. By the use of this heating jet, the metal is first brought to a sufficiently high temperature, and an auxiliary jet of pure oxygen is then turned onto the red-hot metal, when the action just referred to takes place. See Oxy-acetylene Method of Cutting Steel and Iron.

Cutting-Off Machines. In general, any machine which is designed exclusively for cutting either bar stock or structural steel may be considered as a *cutting-off machine,* but this term is usually applied by manufacturers to those machines which rotate the stock and sever it by means of a cutting-off or parting tool; machines which utilize a revolving saw for severing the material are commonly listed as *cold-saw cutting-off machines,* or simply as cold saws. The term "cold" is used in this connection to indicate that the machine is intended for cutting unheated stock. Among other machines used for cutting off stock, which may properly be inserted under the general classification of cutting-off machines, are hacksaw machines, metal-cutting band

saws, abrasive wheel cutting-off machines, and the friction saw. See Cold-Saw Cutting-off Machines.

Cutting Off Stock with Abrasive Wheels. Abrasive wheels formerly were used for cutting off metal only when the material to be cut was such that steel saws could not be used. Today not only is metal bar stock and tubing cut economically with abrasive wheels, but such materials as plastics, glass tubing, porcelain, etc., are being cut—materials that formerly could only be handled by slower and more costly methods. Furthermore, the metals to be cut do not have to be annealed for the cutting-off operation; hence hardened tool steels, and even Stellite, can be cut without injury to the tools.

Wheels Used: There are three types of organic bonds used in the manufacture of abrasive cutting-off wheels—shellac, rubber, and resinoid. The shellac bond produces a soft wheel, suitable for cutting tool steels. Highly heat-sensitive high-carbon and high-speed steels for lathe and planer tool bits, for example, are readily cut without discoloration.

The rubber bond makes practical the manufacture of wheels as thin as 0.005 to 0.006 inch. Such wheels are used for slotting pen nibs. Wheels 0.020 or 0.025 inch thick are used for cutting tungsten rod. Glass tubing is being cut without chipping by wheels from 0.030 to 0.062 inch in thickness. Rubber-bonded wheels are generally used for wet and submerged cutting operations and for certain high-speed cutting jobs where a somewhat flexible wheel is required.

Resinoid-bonded wheels are recommended for dry cutting where "burn" and burring are not objectionable and where the area of cross-section is relatively large. Carbon, plastics, and tile are generally cut wet with resinoid-bonded wheels. With the introduction of resinoid bonds, wheel speeds were gradually increased from 9000 to 16,000 surface feet per minute, corresponding gains in cutting-off time being obtained.

Types of Abrasive Cutting Machines: There are four general classifications of abrasive cutting machines: (1) High-speed machines; (2) low-speed machines; (3) wet and submerged machines; and (4) portable machines.

The high-speed machine must, of necessity, be designed for safe operation of high-speed abrasive wheels. The machine bearings must have no side play, and the movement in the plane of the wheel toward the work must be positive. Wheel balance, thickness variation, and warping or dishing are controlled in the wheel manufacture within narrow limits.

The low-speed cutting machines include a variety of types, from specially designed bench and floor stands with fixtures to

makeshift or revamped equipment. The recommended operating speeds vary from 9000 to 10,000 surface feet per minute.

The wet and submerged types of cutting machines actually belong in the low-speed group; but these machines are designed with the rigidity of high-speed machines. Considerable economy has been obtained in the cutting of tubing by cutting wet at low speed, using rubber-bonded wheels. Metallographic specimens are also cut wet.

In the submerged method, the wheel speed is, in some instances, lower than that of the low-speed machines—sometimes as low as 1200 revolutions per minute, using 12- and 14-inch diameter wheels. Higher speeds tend to make the wheel create a trough in the coolant, and thereby defeat the purpose of this method of cutting. Chipping, burning, and excessive burring will be the result. These machines operate with the work entirely submerged in water or other coolant, and are principally used for cutting glass tubing, porcelain tubes, light-wall metal tubing, and small plastics. Wheels for wet abrasive cutting machines are furnished as thin as 3/32 inch for 16-inch diameter wheels.

Portable cutting machines generally use wheels from 6 to 12 inches in diameter, operating at from 2000 to 2500 revolutions per minute. Machines of this type are used by quarries, building contractors, etc., and also in small metal-working shops.

Cutting Oils and Compounds. Oil or cutting compound is delivered to a metal-cutting tool in order to increase production, to give longer life to the tool, and in some cases to secure a better finish on the work. The functions of an oil or cutting compound may be presented under five heads: (1) To cool the work and cutter. (2) To wash away chips. (3) To lubricate the bearing formed between the chip and lip of the cutting tool. (4) To enable the cutting tool to produce a good finish. (5) To protect the finished product from rust and corrosion.

The cooling action is the most important function. During the performance of any machining operation generation of heat is due to friction between the tool and work, and to distortion of the chips. This results in raising the temperature of both the cutting tool and the work; and if provision is not made for the removal of this heat, the temperature may become so excessive that the cutting edge of the tool breaks down. Another important consideration is the possibility of having the work raised in temperature so that it expands considerably during the machining operation, and while the tools may continue to produce parts of the required size when measured at this high temperature, the work will contract on cooling so that it will be under size. A great variety of oils and cutting compounds are used for metal-cutting tools.

Cutting Saw of Electric Arc Type. The electric arc saw is designed to cut iron, steel, and any ferrous or non-ferrous alloy, as well as tungsten carbide. This machine operates on a low-voltage current applied across the arc. The actual saw unit consists of a soft alloy steel disk provided with a large number of small straight teeth on its outer edge. Cuts are made by means of a controlled electric arc that "leaps" ahead of the saw and brings the metal along the kerf lines to a molten or plastic condition. The saw disk does no actual cutting, but serves to sweep the molten metal from between the kerf lines and acts as an electrode from which the heat generating arc "jumps" to the work. The real function of the saw is to give impulse to an oscillation of the current through a lengthening and shortening of the arc which stabilizes and directs the path of the arc to such an extent that side arcing is eliminated. The arc thus controlled travels in a path a few thousandths of an inch wider than the width of the saw.

Cyanide. Cyanide is a salt of prussic or hydrocyanic acid. The most important of the cyanides commercially is *potassium cyanide,* which is used in the "cyanide process" of gold extraction, and in the mechanical industries as a heating bath for hardening steel, and as a means for casehardening. Cyanide of potassium as a heating bath for heating steel cutting tools, dies, etc., has been utilized in preference to lead heating baths. Cyanide of potassium must be used carefully, because it is a violent poison. The fumes are very injurious and the crucible containing it must be covered with a hood connecting with a chimney or ventilating shaft. The bath is extensively used for hardening when an ornamental color effect is desired on the hardened parts.

Cyanide Coloring of Steel. In using cyanide to color hardened steel, the work is immersed in the bath, brought up to its hardening temperature, and then transferred to a water bath for quenching. At the moment of quenching, the cyanide causes the quenching bath to become violently agitated as a result of the rapid transformation of small quantities of water to steam; this steam and the air drawn into the water by the agitation, partially oxidizes the steel in spots, giving the variegated colors, which are simply intensified tempering colors. While in the cyanide bath the steel is protected from the oxidizing effect of the air and it is also protected during its transfer to the quenching bath by a liquid film of cyanide which adheres to the steel and thus prevents the air from coming in contact with the work. The use of a cyanide pot for complete immersion of the work is more satisfactory than the method of sprinkling powdered cyanide on the work while it is being heated. Fair results can

often be secured by the latter method, but more often the cyanide burns off and the steel is oxidized beyond the temper colors of, say, 650 degrees F. To increase the mosaic effect and obtain brighter colors, hardeners effectively employ either or both of the following methods: (1) Pass the hot steel through a water spray when transferring from the cyanide to the quenching bath. (2) Have a stream of air bubbling through the water in the quenching tank.

Cyanide Hardening. When low-carbon steel requires a very hard outer surface but does not need high shock-resisting qualities, the cyanide hardening process may be employed to produce what is known as superficial hardness. The superficial hardening is the result of carburizing a very thin outer skin which may be only a few thousandths inch thick. The preferable method of cyanide hardening is by immersing the steel in a bath of liquid potassium cyanide or some other mixture containing cyanogen as a base. This carburizing process is, of course, followed by quenching. Another method of cyanide hardening is to sprinkle over the surface of the steel a pulverized cyanide salt which is melted as the steel is heated to the proper temperature. Referring to the first method, which is conducive to greater uniformity in carburizing as well as increased efficiency, the potassium cyanide salt is melted in a pot furnace and the temperature of the molten bath should be slightly over the upper critical range of the salt—say 1550 to 1600 degrees F. The steel ordinarily is immersed for 10 or 15 minutes and it is quenched usually in lime water to neutralize the cyanide remaining on the steel. The pot furnace used should be equipped with a hood for carrying off the fumes as cyanogen compounds are deadly poisonous.

Cyanide-of-Potassium Bath. Cyanide of potassium may be used in preference to lead, for heating steel cutting tools, dies, etc. Sodium cyanide, however, costs less than potassium cyanide and is generally used. When cyanide is used, the parts should be suspended from the side of the crucible by means of wires or wire cloth baskets, to prevent them from sinking to the bottom. Steel will not sink in a lead bath, as lead has a higher specific gravity than steel. Cyanide of potassium should be carefully used, as it is a violent poison. The fumes are very injurious, and the crucible should be enclosed with a hood connecting with a chimney or ventilating shaft. This bath may be used for hardening in gun shops, in order to harden parts and at the same time secure ornamental color effects.

Cycle, Alternating Current. "Cycle," as applied to alternating current, refers to that period of time in which the current

builds up from zero to its maximum, then drops gradually back to zero, and passes through the same increase and decrease in the opposite direction. Thus there are two alternations for each cycle. By the "number of cycles," that is, 60, 50, or 25, is meant the number of complete cycles per second. In other words, for a 60-cycle line there are $60 \times 60 \times 2 = 7200$ alternations per minute.

Cycles, Internal Combustion Engines. Engines of the internal combustion type or those which derive energy from gas, gasoline and other oils, may be divided into two general classes. One class includes engines which operate on the *four-stroke cycle* or the Otto cycle, and the other class includes the *two-stroke cycle* engines. The four-stroke cycle consists of a suction stroke which serves to draw the mixture of air and fuel into the cylinder; a compression stroke during which the charge of air and fuel is compressed into the clearance space; the expansion stroke which follows the ignition of the charge or the explosion of the gaseous mixture; and finally the exhaust stroke which expels the burned charge from the cylinder. Since four piston strokes are thus required to complete one cycle, there is one explosion during two revolutions of the crankshaft; consequently, the flywheel is depended upon to store enough energy to keep the engine moving at a fairly uniform rate during the complete cycle. The two-stroke cycle engines of the ordinary type are so designed that an explosion occurs every revolution of the crank.

Cycle Thread, British Standard. The standard thread which was adopted originally by the Cycle Engineers Institute of Great Britain in 1902 is made with a 60-degree angle and rounded at the top and bottom, the depth of the thread being equal to 0.5327 times the pitch, and the radius of the round at top and bottom being equal to one-sixth of the pitch. The present standard has a range of diameters from 1/8 inch to 3/4 inch, inclusive. The 1/8-inch size has 40 threads per inch; the 5/32- and 3/16-inch sizes have 32 threads per inch, and the larger sizes all have 26 threads per inch.

Cycloid. The cycloid is a geometrical curve which is produced by a point located on the periphery of a circle when the circle rolls along a straight line. A curve known as an *epicycloid* is formed by a point on the circumference of a circle which rolls on the outside of another circle. A *hypocycloid* is produced by a point on the circumference of a circle which rolls along the inside of the circumference of a larger circle.

Cycloidal Gear Teeth. When the outline of gear teeth is formed by an epicycloid above the pitch circle and by a hypo-

cycloid below the pitch circle, the gear teeth so formed are generally known as *cycloidal gear teeth.* The most important point in favor of the cycloidal system of gearing is the freedom from interference of the teeth, but this advantage is considerably modified by the fact that, in order that cycloidal gears shall run properly together, the pitch circle of the two gears must tangent each other; that is, the center distance between the two gears must be very accurate. With involute gears, the distance between the centers may be varied somewhat without affecting the smoothness of the action. Cycloidal gear teeth are seldom used at the present time. Cast gears were in the past always made with this system of teeth; now for cut gearing, and also for a large proportion of cast gearing, the involute system has replaced the cycloidal.

Cylinder-Boring Machine Classification. The general methods of boring and finishing cylinders differ in regard to the method of presenting the tool to the work and of obtaining the necessary rotating and feeding movements. For instance, the tool may be held stationary except for the feeding movement, while the cylinder is revolved, or this order may be reversed. In some cases, the tool is given both a rotating and feeding movement, the exact arrangement depending upon the type or design of the machine. All cylinder boring machines may be included in one of three general classes designated as (1) machines designed exclusively for cylinder boring; (2) machines which may be adapted for cylinder boring but are intended for other operations as well; (3) portable machines or boring-bars which are applied to the cylinder to be bored. The first class includes both horizontal and vertical designs which vary considerably in regard to the general arrangement of the various details. The second class of machines mentioned which are not designed primarily for cylinder boring, but which are adaptable to it, includes such machines as engine lathes, turret lathes, and horizontal and vertical boring machines. The third class includes the various forms of portable boring-bars which have their own feeding mechanism and (with the exception of hand-operated tools for truing small cylinders) are designed for a power drive, either by belt or by a direct-connected motor. The cylinder boring machines of vertical design have been extensively used for automobile engine cylinders.

Cylinder Grinder, Planetary Type. The planetary or eccentric-head type of grinder is so arranged that the cylinder casting does not revolve while being ground. The grinding wheel, as it revolves rapidly about its own axis, is given a relatively slow circular or planetary motion, so that it is carried around the

wall of the cylinder. At the same time, the cylinder, which is mounted on a carriage or slide of the machine, is given a lengthwise feeding movement which, for each complete circular movement of the wheel around the cylinder wall, is somewhat less than the width of the grinding wheel. The spindle-head of the grinding machine is so arranged that the eccentricity of the wheel-spindle or the diameter of the circular path it follows can be varied for grinding different diameters.

Cylinder Strength Formula. See Barlow's Formula.

Cylindrical Grinding Machines. The cylindrical grinder was first made in the early sixties as a grinding lathe by the Brown & Sharpe Mfg. Co., for the grinding of sewing machine parts. The regular manufacture of "grinding lathes" began in 1864, parts of 14-inch Putnam lathes being modified to permit mounting a grinding wheel on the carriage as well as an automatic feeding and reversing attachment and a dead center pulley.

Machines of the cylindrical type are intended primarily for grinding cylindrical parts, although they can also be used for taper work and other grinding operations, the extent of which may be increased considerably by the use of auxiliary equipment. For ordinary cylindrical grinding, the work is held between the centers of the machine, and it is rotated at a comparatively slow speed, while the grinding is done by a rapidly revolving grinding wheel. The machine is usually arranged so that the work is given a lateral feeding movement, in order that the wheel may cover the entire surface to be ground; some machines, however, are so constructed that the work rotates in one position and the wheel is given a traversing movement. Cylindrical grinding machines are equipped with a mechanism which enables the grinding wheel to be fed in automatically toward the work for taking successive cuts.

Cylindrical grinding machines, like milling machines, are divided into two general classes, known as *plain* and *universal* types. The wheel slide of a universal machine can be swiveled with relation to the travel of the table; the headstock can also be set at an angle, and provision is made for revolving the headstock spindle for grinding parts that are held in a chuck or otherwise. With a plain machine, the wheel slide is permanently set at right angles to the table travel and the headstock cannot be swiveled.

D

Dado Joint. This type of joint is used in patternmaking and in other branches of woodworking, for securing the ends of ribs or partitions to the sides of boxes or frames. The rabbet-dado joint is a modified form for corners, which resists both inward and outward pressure. See Joints Used in Patternmaking.

Dalton's Law. A chemical law, known as Dalton's law, states that when two chemical elements form more than one compound with each other, the weights of the one which unite with a fixed weight of another bear a simple ratio to each other. For example, carbon unites with oxygen in two proportions, as carbon monoxide and as carbon dioxide. The latter compound contains the same amount of carbon, but exactly twice as much oxygen as the former. Nitrogen combines with oxygen in five compounds containing respectively two, three, four, and five times as much oxygen as does the first compound, the amount of nitrogen remaining the same. This law is also known as the "Law of Multiple Proportions."

Damascus Steel. A characteristic feature of damascene or Damascus steel is its surface patterns which vary with the carbon content and are either in the form of wavy parallel stripes or mottled patterns. This steel represents an early development in steel making, as it was imported during the Middle Ages to Western Europe through Syria and Palestine, and is known also as Indian steel and bulat. The old Indian method of producing real damascene steel consists in using a pure ore and the best grade of charcoal. The Persian practice is to use soft iron bars and charcoal and plumbago to supply the carbon; and a third method consists of a certain heat-treatment which resembles a prolonged tempering. One investigator has concluded that the carbon, irregularly dispersed in the metal and forming two distinct combinations, is what causes the damask or characteristic pattern and that the slower the cooling the larger the veins will be.

The general but erroneous opinion is that the variegated surface of Oriental swords resulted from their being composed of a compound of bars and wires of iron and steel, welded and wrought together and then twisted by forging in different directions. A dagger blade of good damascene steel, properly hardened, cannot be broken by bending, but can be bent to such an extent that it loses its elasticity. When bent in the usual fashion,

the blade flies back and retains its original shape. When bent more forcibly, the blade may not spring back again, but does not lose its original elasticity after straightening again. An imitation of Damascus steel can be obtained by etching the surface of the steel blade with acids, the parts which are not to be attacked by the acid being protected by a "resist."

Damping. The pointer of an indicating instrument of the type having a hand and graduated scale should preferably come quickly to its correct position on the scale, without oscillating to and fro. This enables readings to be taken with rapidity, and insures that the indications of the instrument follow correctly the fluctuations in the quantity being measured. To overcome the swinging of the moving parts first to one side and then to the other, of the point of rest, it is customary in the construction of electrical measuring instruments, to provide some form of "damping." The retarding force so utilized is produced by the motion of the parts, being zero when there is no motion, but increasing rapidly as the speed of the parts increases. Thus there is no hindrance to the moving element taking its correct position of equality between actuating and counter forces, but violent motions or oscillations are effectively retarded, and the instrument is said to be "dead beat" or "aperiodic."

Three forms of damping are in common use: 1. Air friction. 2. Electrical eddy-currents. 3. Liquid friction. Forms (1) and (3) are similar, in that both employ vanes or surfaces the motions of which are retarded according to the laws of fluid friction. *Air damping,* using light vanes or pistons swinging with small clearances in their enclosing boxes, is widely used for all classes of instruments. *Liquid damping* has more limited application; it is used in certain stationary instruments, and particularly where the parts are heavy and the forces great. In *eddy-current damping,* a conductor which is part of the moving system is arranged to move in the field of a magnet. The action of the resulting eddy-currents in the conductor upon the magnet provides the retarding or damping force. This form of damping is universally used in moving-coil permanent magnet instruments, where the conductor is readily supplied by winding the moving coil on a metal form, the magnet being already present. It is extensively used upon other types of instruments in the form of a metal sector swinging between the poles of a permanent magnet. Its most extensive application is in watt-hour meters, where a disk rotates in the air-gap between the poles of one or more permanent magnets. In this case, however, the damping force is utilized as the counter-force or control, since it fulfills the requirement of being directly proportional in amount to the speed of rotation.

Daniell Cell. The Daniell cell is one of the well-known forms of wet electric batteries. It has a zinc anode and copper cathode with zinc sulphate for the electrode, although sometimes dilute sulphuric acid is used, and copper sulphate for the depolarizer. In its original form, it consists of a glass jar in which is placed the zinc cylinder, and within this a porous cup containing the copper-sulphate solution and the copper cathode. The rest of the jar is filled with zinc-sulphate solution. The E.M.F. depends upon the density of the copper-sulphate solution and on the amount of zinc sulphate present in the dilute sulphuric acid. It is usually only from 1.07 to 1.14 volt.

Darby Process. A method for recarburizing the charge in a Bessemer converter. In this process the carbon is added by throwing anthracite or coke into the casting ladle as the steel is poured into it. The coke or anthracite is placed in large paper bags which have been carefully weighed so that each bag will give from 0.01 to 0.02 per cent of carbon to the steel.

Darcy's Formula. Darcy's formula for the flow of steam in pipes gives the cubic feet of steam per minute which will flow through a pipe when the initial pressure, the terminal pressure, the diameter of the pipe, the weight per cubic foot of the steam at the initial pressure, and the length of the pipe, are known. The formula is of the following form:

$$Q = c\sqrt{\frac{(}{wL}}$$

in which: Q = cubic feet of steam passing through pipe per minute; c = constant found from the accompanying table; P = initial pressure, in pounds per square inch; p = terminal pressure, in pounds per square inch; d = diameter of pipe, in inches;

Table of Constants and Fifth Powers

Diameter of Pipe, Inches	Value of Constant c	Fifth Power of d	Diameter of Pipe, Inches	Value of Constant c	Fifth Power of d
1	45.3	1	5	58.4	3,125
1½	48.5	6	6	59.5	7,776
2	52.7	32	7	60.1	16,807
2½	54.3	97	8	60.7	32,768
3	56.1	243	9	61.2	59,049
3½	57.1	523	10	61.8	100,000
4	57.8	1024	———	———	———

w = weight per cubic foot of steam at the initial pressure P; and L = length of pipe, in feet.

The table which gives the value of the constant c, also contains the fifth power of d, as used in the formula, for certain diameters of pipe.

De-acceleration. De-acceleration or deceleration is the rate of change in the velocity of a moving body when the velocity is decreasing; or, specifically, the decrease in velocity of a body during a very short interval of time, usually one second.

Dead Beat. When the pointer or indicating hand of an electrical or other measuring instrument moves to position without violent and prolonged oscillations, the instrument is said to be "dead beat" or aperiodic. The excessive oscillations are prevented by some method of damping. See Damping.

Dead Center. This term as applied to machine tools relates to the stationary center on which work revolves while being machined. In a lathe, the dead center is that mounted in the tailstock. In grinding machines, both centers frequently are stationary or dead.

An engine is said to be on the "dead center" when the piston is at one end of the stroke, the crank, connecting-rod, and piston-rod being in a straight line. The name "dead center" is derived from the fact that, when the crank and piston are at the end of the stroke, the steam pressure does not exert a turning force upon the crank, the thrust of the piston being transmitted directly to the shaft and bearings.

Decalescence Point. The decalescence point is the temperature at which a decided change in the internal condition of steel takes place, and above which steel must be heated in order that it may be properly hardened by quenching. Generally speaking, the decalescence point of any carbon steel marks the correct quenching temperature of that particular steel. When steel is heated, it reaches a point where it will absorb heat for a brief period without a rise in the degree of temperature of the steel; this point is the decalescence point. As soon as this point has been reached, the steel is ready to be removed from the source of heat; the quenching then checks or traps the steel in the condition into which it has been changed at this temperature. The decalescence point is not the same for all steels, but occurs for most carbon steels at temperatures between 1350 and 1450 degrees F.

Decibel. The decibel is a unit established to indicate the relative intensities of different noises or sounds. When bodies vibrate, sound waves are transmitted through the air, thus caus-

ing sound or noise. These sound waves vary in length and frequency. The latter term indicates the number of waves transmitted per second. The velocity of sound, which is about 1100 feet per second through the air, is practically constant regardless of the frequency or wave length. Velocity is affected slightly by atmospheric temperature changes, there being a variation of about 5 per cent in the ordinary temperature range. The velocity of sound, when transmitted through solids, is very much greater than in passage through the atmosphere. For example, the velocity through steel is about 17,000 feet per second, or over fifteen times the velocity through the air.

Noise or sound intensity may be measured directly in decibels by using a *sound level meter*. A general idea of the relation between the decibel scale and everyday sounds may be obtained from the following comparisons: A whisper is equivalent to about 35 decibels; the noise in an average business office, 65 decibels; the noise made by a passing automobile at 15 to 50 feet, from 75 to 85 decibels; the noise equivalent to heavy street traffic in a city, 105 decibels; and the noise of a subway express train passing through a station, about 115 decibels.

Decking. In a belt conveyor installation, the protection provided for preventing the material being transported from falling onto the reverse side of the lower returning belt is called "decking." If gritty material falls on the reverse side of the belt it will become imbedded as the belt passes over the pulleys, and will gradually wear and destroy the belt.

Decomposition. In chemistry, a chemical reaction in which a compound is divided into two or more products.

Dedendum. Dedendum is the distance from the pitch circle of a gear to the bottom of the tooth space or to the root circle. The *dedendum* is equal to the *addendum* plus the clearance. The addendum of full-depth teeth is equal to 1 divided by the diametral pitch, and the clearance is equal to 0.157 divided by the diametral pitch; hence the dedendum, or depth of the tooth below the pitch-line, is always equal to 1.157 ÷ diametral pitch. In bevel gearing, the dedendum is the depth of the tooth space below the pitch-line at the large end of the tooth.

Deflocculated Graphite. Deflocculated graphite is a lubricant consisting of finely divided graphite suspended in water or oil, by means of a small quantity of gallotannic acid, which, when added to the water, prevents the graphite from settling to the bottom. The graphite seems to entirely dissolve in the water, under these conditions. The black liquid will easily pass through the finest filter paper. Severe tests have demonstrated that it is a satisfactory lubricant. Deflocculated graphite also possesses the re-

markable power of preventing rust or corrosion of iron or steel. The graphite appears to entirely neutralize the effect of the water in which it is suspended. Light and thin oils, when used in conjunction with deflocculated graphite, can be used in place of the heavy and expensive lubricating oils. The lasting qualities of these graphite lubricants are greater than the oil lubricants which they often displace.

Degree. The degree is the unit of angular measurements and is equal to 1/360 of the circumference of a circle. One degree is subdivided into 60 minutes, and 1 minute, into 60 seconds. The degree is also the unit of measurement for temperature, thermometers being graduated in degrees. The value of 1 degree of temperature varies on the different thermometer scales. Electrical degrees are referred to in connection with alternating electric currents. One complete cycle—that is one complete set of positive and negative values of an alternating current—is equal to 360 electrical degrees; hence, an electrical degree is 1/360 of a cycle.

Delta Connections. In a three-phase alternating-current system, the generators and motors are designed with three windings or phases which are either connected in mesh or delta connection, so called because the diagram of the three windings forms a Greek letter "delta" (△), or connected in star, which is then called a Y-connection, because the diagram of the three windings forms a "Y." In the delta connection each end of a winding is connected to the end of another winding, all three forming a closed circuit. In the star connection, one end of each winding is connected to a common point.

Delta Metal. Delta metal is an alloy consisting mainly of copper and zinc with small percentages of iron and tin. The percentages of its composition vary somewhat, but it is composed generally of about 60 per cent of copper, 36 per cent of zinc, 2 per cent of iron, and 2 per cent of tin.

Demagnetizer. Hardened tool-steel parts that have been held on a magnetic chuck become permanently magnetized, and this is also true, in a slight degree, of cast-iron parts. This residual magnetism is objectionable for some classes of work, and a device known as a "demagnetizer" is used for removing it. This apparatus consists of an iron base upon which is mounted a wooden box containing a revolving member in the form of a magnet held in a rotating framework; a pulley for rotating the demagnetizer is provided. The cover of this apparatus is detachable and supports a mass of laminated sheet-iron plates which are in contact with two metal plates attached to the top cover. After the apparatus is set in motion, all traces of magnetism may be removed from the work by simply moving it several times in and out of

contact with these metal plates. The phenomenon of demagnetizing may be briefly explained as follows: The iron plates at the top of the apparatus represent the poles of a magnet in which the polarity is rapidly reversing. This reversal of polarity is transmitted to the work in contact with the plates. At the moment of reversal, however, there is a neutral point in which, for an instant, there is no magnetism. In removing the work out of a strong magnetic field to a weaker one (by lifting it away from the apparatus), it has moved a certain distance during the time that the magnet is neutral, and, when next charged, being in a weaker field, it does not take as strong a charge as before; thus, by a repetition of this movement, the magnetism is finally removed entirely.

Demand Meter. A demand meter records or indicates the maximum average electric power load over any specified time interval, or the average load over a number of equal time intervals. It is frequently installed where there is apt to be a peak demand for power quite in excess of the ordinary load. Its readings then serve as a basis for a demand charge which is in addition to the customary charge for actual power utilized. Since a power company's electric generating and distributing equipment must always be adequate to meet peak demands, a demand charge is made in order to equitably distribute the cost of maintaining and operating such equipment.

Density. The density of any solid, fluid or gaseous substance is the mass of that substance per unit volume. If weight is used in the ordinary sense as being equivalent to mass, then the density may be defined as the weight per unit volume. It is then evident that the numerical value of the density of a substance depends upon the unit in which the mass or weight is expressed, and also upon the unit of volume used. In engineering and scientific work, however, the density of a substance is generally expressed in grams per cubic centimeter, without naming the units, because, when so expressed, the density will, for all practical purposes, be equal to the specific gravity.

Deoxidized Bronze. An alloy containing copper and tin as its chief constituents, generally being composed as follows: Copper, 82.5 per cent; tin, 12 per cent; zinc, 3.4 per cent; lead, 2 per cent; and iron, 0.1 per cent.

Depolarizer. As a result of chemical action in a primary cell, hydrogen may be released and form a film over the surface of the cathode. Hydrogen is a non-conductor, so that a layer of it on the cathode would prevent the passage of the current; a cell in that condition is said to be polarized. Polarization decreases the electromotive force of the cell and may entirely pre-

vent its useful operation. Any substance that, when placed in the electrolyte or on the electrodes, will partly or entirely prevent this collection of hydrogen on the cathode is called a depolarizer. Thus, manganese oxide or some other metallic oxide is used as a depolarizer to release oxygen which combines with the hydrogen to form harmless water. See also Polarization.

Depreciation of Mechanical Equipment. The depreciation or reduction in value of mechanical apparatus is estimated in advance in order to determine what funds should be set aside periodically to provide ultimately for the purchase of new equipment. Depreciation percentages, even for the same types of equipment, vary considerably because they are affected by certain variable factors, such, for example, as (1) extent of wear resulting from use or location of equipment; (2) obsolescence or reduction in value due to development of more efficient apparatus (in this connection either a reduction or an increase in replacement value of new apparatus may have to be considered); (3) care of equipment, both as regards operating conditions and maintenance or repairs. These factors vary widely for different classes of equipment. Certain types of machines and tools, for example, depreciate in value as the result of wear only; whereas other types become obsolete and are uneconomical to use because an improved design or type has been developed. The following depreciation rates, all which are given as percentages of the original cost, have been obtained from various sources. The extreme variations recommended by various authorities are given to indicate the fluctuations under different conditions. The average percentages, together with the number of sources upon which the averages are based, are also included.

Belting: Main belts, range 5 to 25 per cent; average from eleven sources, 12 per cent. Machine belts, 25 to 50 per cent.

Motors: Range 4 to 10 per cent; average from twelve sources, 7 per cent.

Engines, Reciprocating Steam: Range 4 to 10 per cent; average from thirteen sources, 6 per cent. *Engines, Turbine Type:* Range 3 to 7 per cent; average from thirteen sources, 5 per cent. *Engines, Gas:* Range 5 to 10 per cent; average from eight sources, 7 per cent.

Boilers: Range 4 to 10 per cent; average from eighteen sources, 6 per cent.

Pumps: Range 3½ to 8 per cent; average from nine sources, 5 per cent.

Hoists: Range 7 to 12 per cent.

Cranes: Range 2 to 10 per cent; average from eight sources, 6 per cent.

Machine Tools: Common range for standard types subject to normal usage, 5 to 10 per cent. For manufacturing types or special designs used continuously, the range may vary from 15 to 30 per cent. Each type of machine tool must be considered separately because of the wide variety of operating conditions and also on account of the numerous developments in the machine tool industry which cannot be predetermined.

Machinery in General: Range 5 to 13 per cent; average from eight sources, 9 per cent.

Dies: Range 25 to 50 per cent; average from four sources, 40 per cent. The cost of tools of this class, when made for a particular order, should be charged to that order.

Hammers, Drop and Steam: 10 per cent.

Patterns: Range 20 to 100 per cent; average from six sources, 65 per cent. Metal patterns have a lower depreciation rate than wood patterns, but in any case when patterns are for a particular job, the entire cost should be charged to that job.

The foregoing figures are intended chiefly as a general guide.

Descaling Apparatus. An oxy-acetylene type of descaling apparatus is used for removing scale or similar accumulations from iron and steel by rapidly heating the deposits with multi-flame tips. This heating causes the scale to crack off as a result of the difference in the rate of expansion between the scale and the base metal. The process is adapted for removing scale from ingots, billets, and slabs to expose seams and defects for inspection prior to scarfing or chipping. It can also be used for removing scale from forgings and steel castings prior to machining, as well as from steel castings after annealing.

Another important function of the apparatus is the driving out of the occluded moisture from within and beneath the surface scale of structural steel and plate by rapidly heating the surface with the high-temperaure flames, leaving a warmed surface for painting. Immediately after the flame application, the surface is wire-brushed and swept clean of loosened scale particles and dust. The painting is then done before recondensation of moisture occurs. An ideal paint base is thus provided and the danger of further loosening of the protective mill-scale through weathering is minimized.

Design Patent. In the language of patent law, the word "design" does not mean the physical arrangement of the parts of a machine, but refers solely to its ornamental appearance. A design patent gives its inventor a monopoly to the exterior appearance of the thing patented.

A design patent may be obtained by any person who has invented any new, original, and ornamental design for any article

intended to be manufactured, but the interior views, or other parts that will not be seen when the apparatus actually is performing its service, cannot be protected. A simple legal form, together with the required drawing, comprises a complete application for a design patent. See Patent on Design.

Dessiatine. A Russian square measure, equal to 2.7 acres.

Detinning. The recovering of tin from tin scrap, old tin cans, etc., is known as *detinning*. Two methods are in use for this purpose. One method is based upon purely chemical means, the tin being converted into tin tetrachloride by treating it with dry chlorine. The other method is electrolytic, the tin being dissolved and deposited in the metallic state.

Diagrams. Diagrams are used for obtaining unknown factors in a problem without carrying out the calculations required in figures; they may also be used for checking the results of calculations made by figures. The results are obtained by simply following the lines in the diagram in a certain manner, which may be different for different diagrams. Each diagram covers a large number of problems of the same type, but for different kinds of problems other diagrams must be devised.

Practically all engineering information that can be presented in tabular form can be arranged also in the form of a diagram. There is, however, a very distinct difference between the kind of information that can best be recorded in diagrams and in tabular form. When there are only a comparatively few dimensions or sizes, varying by definite intervals, a table is better than a diagram; for example, if it is desired to list dimensions of machine details that are made in a specified number of sizes, a table giving the necessary dimensions has every advantage over a diagram. On the other hand, when there is a large number of combinations of different factors, the diagram performs a service that a table cannot, unless it is made so large and elaborate as to be impracticable. For example, a diagram relating to the horsepower transmitted by gears of different pitches, widths of face, numbers of teeth, and running at different speeds, is entirely practicable; whereas a table giving all such possible combinations would be too voluminous.

Whenever all the facts can be simply and easily recorded in a table, that method is generally best. If the variables are so many that a table becomes too voluminous, then the diagram will best fill the requirements.

Often diagrams are useful for visualizing a trend or tendency, because a curve will show this much more clearly than a set of figures. This, however, is a use for the diagram distinctly separate from that contemplated in the foregoing, where tables and

diagrams are used merely as convenient methods for recording information, and for obtaining unknown dimensions and sizes that depend upon, or correspond to, some known dimension.

Diagrams, Valve. See Valve Diagrams.

Dial Feeding Mechanisms. Automatic feeding mechanisms of the dial type are used in conjunction with power presses for parts which have been partly finished by previous operations. The parts to be operated upon are placed in the pockets of the dial feeding mechanism, and as the punch descends the dial revolves automatically, stopping just before the punch enters a pocket. After the operation is performed, the part is automatically ejected from the dial, leaving the pocket empty for another cup or blank. There are two different types of dial feeds in general use. The *friction-dial feed* consists of a plain disk which revolves continuously in combination with stationary guides and gages above it, so that the pieces placed on the disk are fed accurately under the punch. In order to insure reliable action, there is usually a finger or gripping movement which places and holds the work in the correct position. The friction-dial feed is preferable for redrawing short shells or pieces which are not liable to topple over. The other type is known as the *ratchet-dial feed* and consists of a circular plate which connects with the main shaft through a medium of cams and pawls so as to receive an intermittent rotary motion. This disk has a number of holes or pockets to receive either the work or dies. By means of this feed, it is possible, in many cases, to subject the pieces to two or three consecutive operations without rehandling. Feed mechanisms of the dial type are commonly used for carrying blanks, shells, or cup-shaped parts under the punch to receive a second and third operation. They are extensively employed in connection with the manufacture of brass goods, trimming, buttons, catridge and primer shells, and tubes for pen and pencil cases, and many other specialties.

Dial Gage. The dial gage is a form of gage having a graduated dial and a hand which is connected to a test-point by a system of multiplying levers, so that a very slight movement of the test-point is greatly magnified by the indicating hand. This test-point is placed in contact with the part to be tested, and variations, either in size, alignment, or concentricity, depending upon how the gage is used, are shown by the movements of the hand relative to the dial, which is graduated to read to thousandths of an inch. Dial gages are used in combination with many different forms of gaging devices.

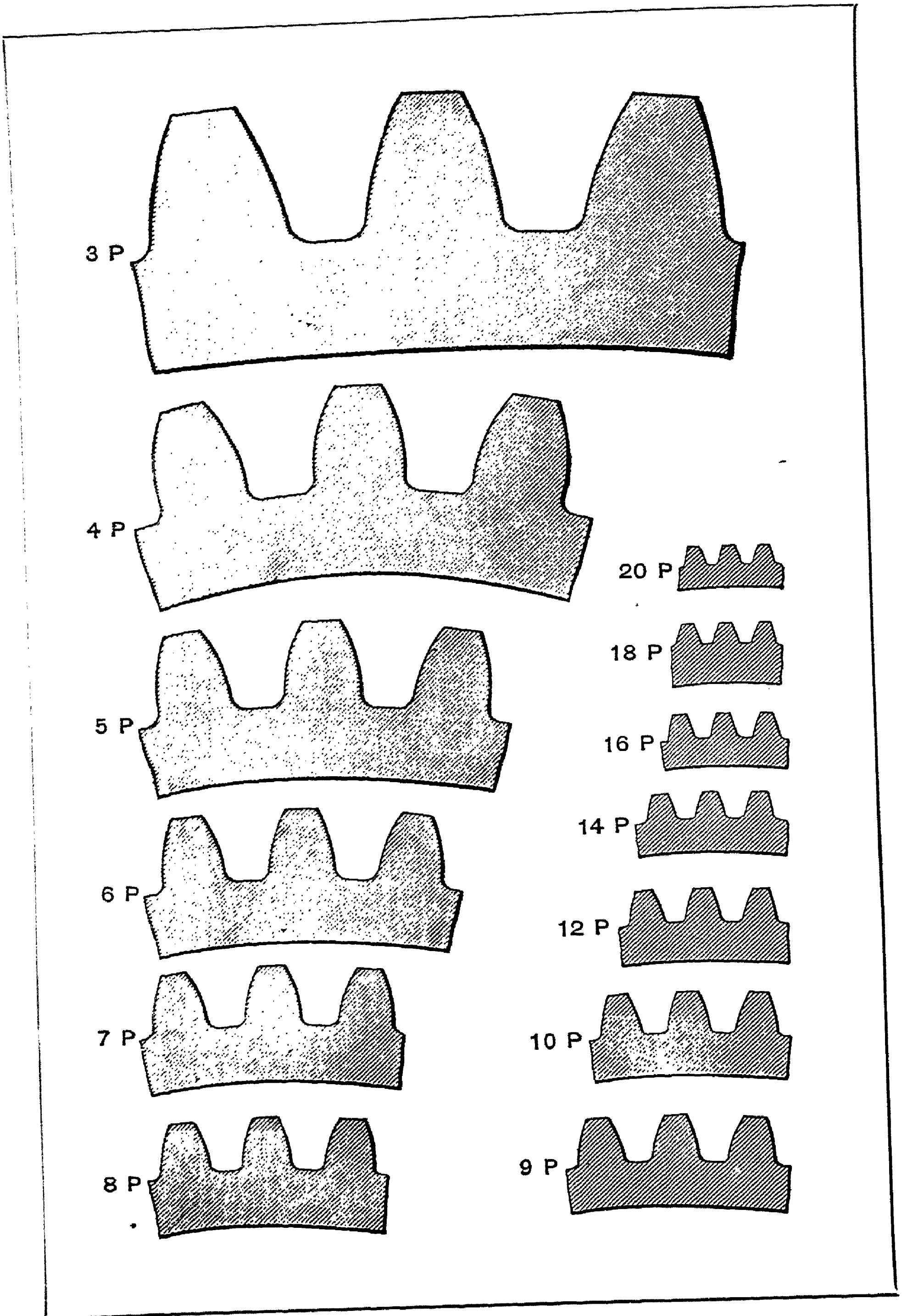
Diamagnetism. Materials, like iron and steel, that are attracted by the poles of a magnet, are known as "magnetic"; those

that are not attracted by a magnet are generally known as "non-magnetic." It has been shown, however, that practically all substances are acted upon in some maner by a sufficiently strong magnetic pole, but only a comparatively small number are attracted like iron, while the great majority of materials are repelled. Those substances that are repelled by the magnetic pole have been termed "diamagnetic." The strongest of all diamagnetic metals is bismuth; that is, of all substances this metal is repelled by a magnetic pole more than any other. Its diamagnetic qualities are so pronounced, in fact, that they can be detected by means of any good permanent magnet. Of the metals, gold, silver, copper, lead, zinc, antimony, mercury, and bismuth are all diamagnetic, while tin, aluminum, and platinum are attracted by a very strong magnetic pole.

Diametral Pitch. The common method of designating the size of the teeth of cut gearing is by giving the *diametral pitch*, which is a number representing the number of gear teeth per inch of pitch diameter. For example, a gear of 6 diametral pitch has 6 teeth around its circumference for each inch of pitch diameter; therefore, if a gear of 6 pitch has 60 teeth, the pitch diameter must equal $60 \div 6 = 10$ inches. The *circular pitch*, which is sometimes used for designating the sizes of very large gear teeth and especially for cast gears, is equal to the dimension from the center of one tooth to the center of the next one measured along the pitch circle. If 3.1416 is divided by the circular pitch, the equivalent diametral pitch will be found, and inversely, if 3.1416 is divided by the diametral pitch, the result will equal the circular pitch.

The diametral pitch system is so arranged as to provide a series of tooth sizes, just as the pitches of screw threads are standardized. (See illustration.) Inasmuch as there must be a whole number of teeth in each gear, it is apparent that gears of a given pitch vary in diameter according to the number of teeth. Suppose, for example, that a series of gears are of 4 diametral pitch. Then the pitch diameter of a gear having, say, 20 teeth will be 5 inches; 21 teeth, 5¼ inches; 22 teeth, 5½ inches, and so on. It will be seen that the increase in diameter for each additional tooth is equal to ¼ inch for 4 diametral pitch. Similarly for 2 diametral pitch the variations for successive numbers of teeth would equal ½ inch, and for 10 diametral pitch the variations would equal 1/10 inch, etc.

The center-to-center distance between two gears is equal to one half the total number of teeth in the gears divided by the diametral pitch. While it may be desirable at times to have a center distance which cannot be obtained exactly by any combination of gearing of given diametral pitch, this is an unusual



Gear Teeth of Different Pitches Shown Full Size

condition and ordinarily the designer of a machine can alter the center distance whatever slight amount may be required for gearing of the desired ratio and pitch. By using a standard system of pitches all calculations are simplified, and it is also possible to obtain the benefits of standardization in the manufacturing of gears and gear-cutters. The range of diametral pitches ordinarily used is 1, 1¼, 1½, 1¾, 2, 2¼, 2½, 2¾, 3, 3½, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16, 18, and 20. For very small gears, finer pitches of even number diametral pitches are employed. The diametral pitch system, which was long known as the "Manchester pitch," was originated by a Swiss named John George Bodmer, in his plant at Manchester, England.

Diametral Pitch in Plane of Rotation. Formulas for designing herringbone gears often contain what is termed "diametral pitch in plane of rotation." The diametral pitch in plane of rotation equals the number of gear teeth divided by the pitch diameter, the same as in the case of a spur gear. The diametral pitch obtained in this way may either be some standard pitch or it may be an odd fractional pitch. Diametral pitches such as 2, 2½, 3, 3½, 4, 5, 6, etc., are examples of standard diametral pitches such as are found in tables of tooth parts.

Herringbone-gear teeth are cut to some standard tooth depth. The stub form of tooth is the most common, and the total depth of the American standard stub tooth equals 1.8 divided by some standard diametral pitch. If a full-depth tooth is required, then 2.157 is divided by some standard diametral pitch. If the diametral pitch in the plane of rotation is not standard, it cannot be used in formulas for addendum, dedendum and total depth, because the tooth depth would not be standard. Herringbone gear designing problems may be divided into three very general classes. In considering these three classes or cases, reference to diametral pitch will be made by way of illustration, but the same principle would apply if the gear were designed on the basis of circular pitch.

Case 1: When a special herringbone-gear hob or cutter is used having some standard diametral pitch in the plane of rotation: Such a hob or cutter is special in that the tooth thickness is reduced an amount depending upon the helix angle, thus making the circular pitch of the gear in the plane of rotation equivalent to a standard diametral pitch.

Case 2: When a standard spur-gear hob is used because a herringbone-gear hob is not available: In this case the diametral pitch of the hob represents the normal diametral pitch of the gear and the diametral pitch in the plane of rotation will be an odd fractional pitch unless the pitch in the plane of rotation is also made standard, as explained in the next paragraph.

Case 3: When a standard spur-gear hob or cutter is used and a special helix angle is selected to make the diametral pitch in the plane of rotation standard as when spur gears are to be replaced by herringbone gears without changing the center distances between the shafts or the ratio.

Diamond. A form of the chemical element carbon which is extremely hard. In its pure form, it is exceedingly clear and transparent, but numerous impure varieties, known as "black diamond" and "bort," are dark in color. These latter are used in the industries for dressing grinding wheels, and in some cases for cutting tools. The specific gravity of carbon in the form of diamond is about 3.5.

Diamond Chisel. A chisel with a narrow blade having the cutting edge at one corner of a square-shaped end. It is intended for cutting V-grooves having a sharp bottom.

Diamond Dust. Diamond dust is commonly used for lapping or grinding small precision work in tool-rooms, watch factories, etc., where great accuracy is required. The grades of diamond dust used for charging laps are designated by numbers, the fineness of the dust increasing as the numbers increase. The diamond, after being crushed to powder in a mortar, is thoroughly mixed with high-grade olive oil. This mixture is allowed to stand 5 minutes and then the oil is poured into another receptacle. The coarse sediment which is left is removed and labeled No. 0, according to one system. The oil poured from No. 0 is again stirred and allowed to stand 10 minutes, after which it is poured into another receptacle and the sediment remaining is labeled No. 1. This operation is repeated until practically all of the dust has been recovered from the oil, the time that the oil is allowed to stand being increased finally to several hours, in order to obtain the smaller particles that require a longer time for precipitation.

Diamond Lap. Very small holes in precision work are often finished after drilling, by using a rotary diamond-charged lap. Laps of this kind are made of mild steel, and the slightly enlarged working end is charged with diamond dust, thus converting it into an efficient grinding wheel for small holes. Such a lap may be charged by rolling it between hardened steel plates, after placing a little diamond dust and oil on the lower plate. The spindle is revolved by a round belt connecting with the grinding pulley on the countershaft. The spindle speeds for small grinding and lapping operations usually vary from 10,000 to 12,000 revolutions per minute.

Diamond or Precision Boring. The expression "diamond boring" or "precision boring" is applied particularly to the boring

of holes on machines designed for high speeds and the use of carbide or diamond boring tools. Diamonds have long been used for machining materials that were too hard to yield to the cutting edges of steel tools, but their use for machining the softer materials requiring an extremely hard tool is a later development. After tungsten carbide became available, it was used in place of diamond tools for most precision boring operations. The cemented tungsten-carbide boring tools are used in the form of small cutting tips, brazed into tool-holders. The term "diamond boring" is often applied even when carbide tools are used. Light cuts and fine feeds are employed in precision boring and to obtain the best results, the cutting edge must be lapped to a high polish, so that there will be no grinding marks on the cutting edge.

Tungsten carbide, like the diamond, must be used where vibration is reduced to a minimum. If there is any considerable amount of vibration, the keen hard cutting edge of the tungsten carbide will be destroyed. Tungsten carbide is capable of scratching a sapphire, which is next to the diamond in hardness. The hardness is approximately 90 on the Rockwell A hardness scale. while the diamond hardness is 100. Tungsten carbide, however, is more uniform and dependable than a diamond, and is not so likely to chip. Moreover, the cutting face and edge desired can be more readily obtained on tungsten carbide when sharpening.

Diamonds for Wheel-Truing. There are five different kinds of diamonds employed for truing grinding wheels, namely, Jaegers-Fontin, Ballas, black carbon, brown bort, and gray bort. The Jaegers-Fontin diamond is very hard and is the most brittle kind. It is grayish in color, irregular in shape, and possesses a very coarse grain. It fractures easily, usually at the wearing point, which chips off in little pieces. It may be set firmly without difficulty on account of its rough surface, but this surface makes it difficult to true wheels satisfactorily. In addition to these disadvantages, these diamonds are very expensive.

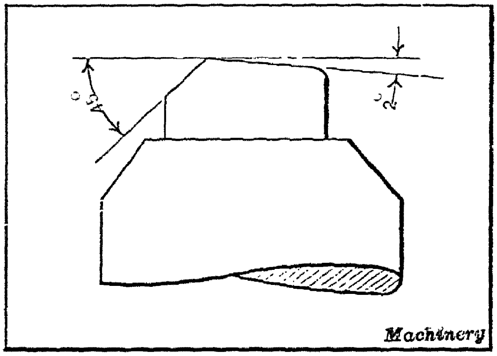
The Ballas type of diamond is a clear white stone, hard and brittle, but not to the same degree as the Jaegers-Fontin type. It is of a finer grain than the latter and generally gives more satisfactory results. The black diamond is soft but tough. It does not break but wears too quickly to be suitable for the purpose of truing grinding wheels. It is also very expensive. Of the bort types, the brown stone has a smooth surface and a fine grain, and is transparent. It is not as hard, however, as either the Jaegers-Fontin or the Ballas types, but it is very tough. The color of the stone is produced by the presence of iron oxide. The gray stone is much the same as the brown stone except for the color and for the fact that it is a little harder and more brittle. The bort stones are sufficiently hard to withstand all reasonable wear, their

shape is such as to permit them to be securely set and they are relatively inexpensive.

The shape of the wheel-truing diamond is an important factor in determining its value, the ideal shape being an eight-sided stone. The diameter and face of the grinding wheel, its hardness, and the type of abrasive used are factors which should be considered when determining the proper size of stone to use. A diamond should never be used on a grinding wheel which is mounted on a loose spindle, as the tendency will be to shatter the diamond and probably to pulverize it. The diamond should never be rammed into the grinding wheel, and should not be traversed across the face of the wheel too quickly. It is important that a stream of water be used during the truing-up operation.

Diamond Substitute. A material which is intended to replace diamonds in stone-cutting and core-drilling is known as phoran. See Phoran.

Diamond Tools for Metal Cutting. Tools with diamond cutting points have been used to a limited extent for certain metal-cutting operations on precision work, especially when a tool of extreme durability is required to obtain the necessary accuracy. Diamond tools, however, have been replaced largely by the cemented carbide tools. Diamond tools have been used chiefly for machining non-ferrous metals, such as brass, bronze, aluminum and German silver. Various non-metallic materials may be cut readily with diamond tools, as, for example, hard rubber, fiber, strawboard, gutta-percha, and bakelite. Diamond tools are especially adapted to fine instrument and tool work.



Shape of Diamond for Turning Operations

Kinds of Diamonds Used: Brown Brazilian or African diamonds which are off color and unsuitable for jewelry are used for metal cutting. Black or "carbon" diamonds used in dressing grinding wheels have been used, and while satisfactory results were obtained in cutting rubber, bakelite, etc., these diamonds were found unsuited for the precision cutting of metals. It is essential that the diamonds used for this purpose be of close grain and free from carbon spots, so that a keen cutting edge may be ground. The largest diamonds used for industrial purposes are about 20 carats, and the smallest size used in a cutting tool,

$\frac{1}{8}$ carat. It is advisable to use a diamond of the largest possible size that is suitable for the work at hand, as this permits the diamond to be reset if necessary; also a large diamond has a greater percentage of salvage value than a small diamond, thus making the net cost much less.

Shape of Diamond Tool: Diamonds can be ground for outside turning, boring, radius turning, facing, and, in fact, for almost any lathe operation for which high-speed steel tools are suited. Pointed tools are ground to various included angles between 60 and 120 degrees. Turning tools are usually ground to a 45-degree angle at the left-hand end of the cutting edge (see illustration), the width of the bevel depending upon the depth of cut to be taken with the tool. The wide front portion of the cutting edge is ground at an angle of 2 degrees from the bevel, and a clearance of 2 degrees is ground on the front face of the diamond when the tool is to be used for cutting brass and aluminum.

Diamond Wire-Drawing Dies. Dies made from diamonds are used extensively for drawing small sizes of wire. Such dies are now employed almost exclusively for wire ranging from 0.080 inch down to 0.0004 inch in diameter; and owing to their durability and other advantageous features, diamond dies are now finding quite a wide application for drawing larger sizes of wire. When they are properly made, the use of these dies is economical. Although their first cost is high, diamond dies retain their accuracy for a long time and they can be repeatedly recut, so that the item of die cost which must be charged against the expense of manufacturing wire, is distributed over a very large quantity of the product. For this reason, diamond dies have largely replaced the use of dies made from steel, iron, ruby, or sapphire. Most diamond dies are made of rough diamonds from the South African and Australian mines, the diamonds used for this purpose being of a grade which is unsuitable for use in jewelry.

These dies consist of a body made from brass or bronze through which is drilled a clearance hole for the wire, which hole is counterbored to a certain depth. The counterbored hole constitutes a seat for the diamond which is set in the center of the hole with molten brass or solder poured in around it until the hole is filled. The diamond is perforated by a tapering polished hole through which the wire is drawn. In many wire-drawing mills, the sizes for which diamond dies are used are limited to from 0.002 to 0.040 inch. The size of diamond for a wire 0.040 inch in diameter is about 3 or $3\frac{1}{2}$ carats, while $\frac{1}{2}$-carat stones will suffice for dies for drawing wire 0.010 inch in diameter.

Dibasic Acid. In chemistry, an acid which has two atoms of hydrogen in each molecule replaceable by a metal.

Die. The term "die" is often applied to an entire press tool including both upper and lower members, while the names "punch" and "die" are used to designate parts or sections of a complete die. These main sections ordinarily are classified with reference to shape, rather than by location, notwithstanding the fact that the punch is usually but not invariably the upper member. When the name "die" is applied to part of a press tool, it refers to the member that has an opening or cavity to receive a punch, for blanking, drawing, or otherwise forming whatever stock or part is confined between the punch and die members. See also Punch.

Die-Block. A block in which the die is held in a punch press. The die-block itself is bolted to the bed of the press. It is also known as Bolster.

Die-Casting. The term "die-casting" generally refers to a casting that has been made in a metallic mold or die, into which molten metal has been forced under the influence of either mechanical or pneumatic pressure. Die-castings do not include so-called "hot-pressed" or "die-pressed" forgings, because in this process, the metal placed in the dies is not molten, but merely in a plastic or semi-plastic condition. The definition also excludes castings that are poured by gravity into metallic molds, the latter generally being known as "permanent-mold" castings. Die-castings may be defined as castings produced by forcing molten metal into metallic dies by a force greater than atmospheric pressure. This definition differentiates them from the class of castings made by the permanent mold process, sometimes referred to as die-castings. Die-castings are uniform, accurate, and cheap, equal to the product of a skilled workman, but produced by unskilled labor. Their advantage over machined parts is due to the rapidity with which they are produced and the relatively small amount of labor necessary after they are cast to produce a finished piece ready to be assembled.

The process of die-casting requires the use of a die-casting machine, and consists essentially in melting the die-casting alloy in a suitable container and forcing it, under pressure, into metallic molds or dies, allowing it to cool in them, and then opening the dies and removing the casting, thereby producing smooth finished castings requiring little or no machining and being ready for buffing or plating without any grinding or other abrasive process. The method is best adapted to small intricate parts where accuracy and uniformity are essential. The history of type founding shows that in 1838 the first casting machine for type, invented by Bruce, was a machine that involved the principles of die casting as it is now practiced. More recently, in 1885, Mergenthaler brought out the linotype machine. This machine is a

good example of a die-casting machine. However, as understood to-day, *die casting* is a broader term than *type casting*, although its development is, without doubt, due, in part, to the success of the linotype machine. The properties of die-castings will depend upon the nature of the alloy used. The die-casting process is best adapted to alloys of comparatively low fusing points which, for convenience, may be divided into the following groups:

Die-Casting Alloys. The alloys used in modern die-casting practice may be divided into five main classifications as follows: (1) Zinc-base alloys; (2) tin-base alloys; (3) lead-base alloys; (4) aluminum-base alloys; and (5) copper-base or brass and bronze alloys.

Zinc-base Alloys: The alloys in this group are produced by alloying zinc with aluminum and copper. The S.A.E. standard zinc-base alloy No. 903 contains, in percentages: Aluminum, 3½ to 4½; copper, maximum, 0.10; iron, maximum, 0.10; tin, maximum, 0.005; lead, maximum, 0.007; cadmium, maximum, 0.005; magnesium, 0.03 to 0.08; and the remainder zinc. The tensile strength should exceed 35,000 pounds and may be as high as 48,000 pounds per square inch. S.A.E. Composition 921 is quite similar to 903, excepting the copper content which is 2½ to 3½ per cent. These two alloys are generally used for hardware and such parts as radiator caps, lamp brackets, housings, parts of household utensils, cash registers, vending machines, etc. No. 921 is inferior to 903 in permanence of dimensions and retention of impact strength, but it is superior in tensile strength which should be in excess of 44,000 pounds per square inch.

Tin-base Alloys: In this group tin is alloyed with copper, antimony, and lead. S.A.E. Alloy No. 10 contains, as the principal ingredients, in percentages, tin, 90; copper, 4 to 5; antimony, 4 to 5; lead, maximum, 0.35. This high-quality babbitt mixture is used for main-shaft and connecting-rod bearings or bronze-backed bearings in the automotive and aircraft industries. S.A.E. No. 11, which contains a little more copper and antimony and about 4 per cent less tin, is also used for bearings or other applications requiring a high-class tin-base alloy. S.A.E. Alloy No. 12 is relatively inexpensive because of the high lead content of 26 per cent. These tin-base compositions are used chiefly for automotive bearings but they are also used for different classes of die-castings, especially for milking machines, soda fountains, syrup pumps, and similar apparatus requiring resistance against the action of acids, alkalies, and moisture.

Lead-base Alloys: These alloys are employed usually where a cheap non-corrosive metal is needed and strength is relatively unimportant. Such alloys are used for parts which must withstand the action of strong mineral acids and for parts of X-ray

apparatus. S.A.E. Composition No. 13 contains (in percentages) lead, 86; antimony, 9.25 to 10.75; tin, 4.5 to 5.5 per cent. S.A.E. Specification No. 14 contains less lead and more antimony and copper. The lead content is 76; antimony, 14 to 16; and tin, 9.25 to 10.75 per cent. These alloys, Nos. 13 and 14, are inexpensive owing to the high lead content and may be used for bearings which are large and subjected to light service. They are also suitable for some die-castings, but should not be substituted for an alloy with a high tin content.

Aluminum-base Alloys: Aluminum die-castings are used for many parts requiring lightness, strength, and resistance to corrosion. These alloys will take and hold a high polish, and are used for vacuum cleaners and other household utensils, camera parts, motor and instrument housings, etc. There are many compositions limited practically to two general groups, namely, the aluminum-copper and the aluminum-silicon alloys. S.A.E. Alloy No. 312 (generally known as No. 12) is an inexpensive general-purpose alloy, and has been used in the United States more than any other aluminum casting alloy. The main elements, in addition to aluminum, are: Copper, 7 to 9; iron, maximum, 2.5; and silicon, 1 to 2 per cent. The tensile strength should be about 33,000 pounds per square inch. A typical aluminum-silicon alloy contains, in addition to aluminum: Silicon, 12; iron, 2, maximum; copper, 0.60 maximum. The tensile strength is about 30,000 to 33,000 pounds per square inch. S.A.E. Alloy No. 305 contains 11 to 13 per cent silicon, and is especially resistant to salt-water corrosion. These alloys because of their fluidity are adapted for thin-walled castings or for complicated castings consisting of both thin and heavy sections.

Copper-base Alloys: In producing die-castings, the use of alloys having relatively high melting temperatures naturally presents difficulties not occurring with lower melting points, especially in regard to the life of the die-casting dies. Thus, in casting copper-base alloys, it has been necessary to develop special alloy steels and casting methods. The well-known plunger type and "goose-neck" types of die-casting machines are not suitable for brass or bronze alloys. The latter, when cast, are handled in small charges and forced into the die at an unusual speed and pressure. Zinc, for instance, is cast at pressures of 800 to 1000 pounds per square inch; aluminum, at from 400 to 500; and brass, at about 20,000 pounds per square inch. A typical copper-base alloy contains (in percentages) about 57 to 59 copper, 40 to 42 zinc, and 0.5 to 1.5 tin, and the tensile strength is around 65,000 to 75,000 pounds per square inch.

Die Chasers. The inserted cutters used in threading dies are commonly known as *chasers.* These chasers are rigidly fixed in

some dies; in others, they are adjustable radially within a limited range for cutting threads slightly under or over the normal diameter of the die. The chasers on automatic or self-opening dies may be withdrawn far enough to clear the thread and thus avoid backing off.

Die Clearance, Angular. The amount of angular clearance ordinarily given a blanking die varies from one to two degrees, although dies that are to be used for producing a comparatively small number of blanks are sometimes given a clearance angle of four or five degrees to facilitate making the die. See also Punch and Die Clearance.

Die Cushions. The term "die cushions" is applied to some pressure attachments for drawing dies, especially the pneumatic type. See Pressure Attachments for Drawing Dies.

Die-Holders. The die-holders used for solid or non-opening dies may be of the rigid type, the floating non-releasing type, or the releasing type. For turret lathe and automatic screw machine work, the non-releasing type, which is free to move in a lengthwise direction a limited amount, is used extensively, although the releasing design is preferable under certain conditions. With this latter type the die is released or is not held against rotation after the thread has been cut to the required length. When the forward motion of the turret slide discontinues, the rotation of the screw thread draws one section of the releasing die-holder farther forward until the driving connection between the two sections disengages; the die then continues to revolve with the work as long as the latter continues to run forward. When the spindle is reversed the die starts to rotate backward with it, but this reverse movement is stopped automatically by the die-holder, and the stationary die is then backed off the screw as the spindle continues its reverse rotation.

The releasing type of die-holder (which is intended only for non-opening dies) is used when it is necessary to govern closely the length of the thread, as, for example, when cutting a thread close to a shoulder. If the reversal of the machine is controlled by the operator, as in a hand screw machine, a releasing die-holder should be used, because, if the machine is not reversed at the instant a die of the non-opening type reaches the limit of its forward travel, the thread may be stripped or the die broken when attempting to cut close to a shoulder. When the releasing type of holder is applied to the threading spindle of a multiple-spindle automatic screw machine, if the threading operation is completed before the other operations, the releasing device permits the die to revolve loosely until all the operations are completed.

Dielectric. In electricity, the word *dielectric* indicates a nonconductor of electricity. A dielectric body, therefore, is an insulating body. It is characterized by the fact that the energy required to establish an electric field in it is recoverable, in whole or in part, as electric energy. The dielectric strength of a substance is the measure of its insulating qualities; the greater the dielectric strength, the better the material is as an insulating means. Dielectric strength is often indicated by stating the puncturing voltage for a unit thickness which is measured either in centimeters or mils (one thousandth of an inch equals 1 mil). A vacuum is a dielectric. See also Insulating Materials.

Die-Pressed Castings. See Brass Forging and Hot-pressed Brass Parts; also Cold-pressed Castings.

Die-Pressed Steel Parts. See Hot-pressed Steel Parts; also Cold-pressed Forgings.

Dies. See type of die: Bending Dies; Blanking Dies; Burnishing Dies; Compound Dies; Curling and Wiring Dies; Drawing Dies; Embossing Dies; Follow Dies; Forming Dies; Gang or Multiple Dies.

Dies, Chromium Plated. See Chromium Plating.

Dies, Drop-Forging. See Drop-forging Die Materials.

Diesel Engines. The Diesel engine is an internal combustion engine which uses oil as a fuel, and which differs from other types of oil engines principally in that the fuel is introduced directly into the cylinder of the engine without previous gasifying or vaporizing, it being merely introduced in the form of a spray by an atomizer, and in that the engine requires no special ignition device. In the four-stroke cycle Diesel engine, therefore, air alone is drawn into the cylinder on the charging stroke, this air being compressed on the return stroke to a very high pressure—about 500 pounds per square inch—the result of the compression being that the air is heated to a high temperature and that the heavy oil injected into the air at the end of the stroke will be immediately ignited by it. The oil burns rapidly, but without explosion, the pressure exerted by the expansion due to the combustion of the oil producing the power impulse on the piston. Hence, the Diesel engine embodies two distinct features in which it differs from other internal combustion engines: the compression pressure is much higher than that in any other oil or gas engine, and igniting devices are not required, as the temperature of the compressed air is high enough to cause ignition of the oil.

Diesel engines may be broadly divided into two main types or classes: (1) The four-stroke cycle and (2) the two-stroke cycle engine. In both types of engines, the cylinder is filled with air

at atmospheric pressure, the air being compressed by the piston until the pressure becomes about 500 pounds per square inch, and the compression raising the temperature to about 1000 degrees F or more. At this instant a small quantity of oil fuel is forced into the very hot high-pressure air by means of a blast of air at still higher pressure. The oil is broken into a fine spray and its admission lasts only for about one-tenth of the downward stroke. During this short time the oil is burned in the hot air, producing a fairly constant pressure equal to the compression pressure at the end of the compression stroke.

The Diesel engine was invented by Rudolf Diesel, a German engineer, who secured the first patents in Germany on this engine in 1893, and who brought out the first successful engine in 1897 at the Augsburg Works, in Germany.

Die-Sinking. Die-sinking is the process of forming an impression in a die (usually for drop forging). It is done by means of a die-sinking type of milling machine in conjunction with hand chipping, filing, scraping, and "typing" if necessary.

A *die-sinking machine* is a type of vertical-spindle milling machine especially designed for the use of diemakers in milling out the impressions in drop-forging dies, etc., or for finishing recesses of circular or irregular shape. The simple type of die-sinking machine is largely manipulated by hand. In the operation of the Keller die-sinking machine, the cutter is guided over the work and in and out by means of a tracer point which follows the outline and contour of a model or master placed directly above the work. This master may be made either of plaster, cement, or wood. Only a slight pressure is exerted against the master by the tracer, while at the same time sufficient pressure is applied to the cutting tool. Rectilinear motions in three directions are provided, these motions being obtained by means of lead-screws which operate the different slides. Automatic feeds are provided both vertically and horizontally and there is a quick return in both directions for the horizontal movement. There is also a contouring or profiling movement by means of which a templet, or the ridges or grooves of a master, may be followed. When the work leaves the machine, it requires only a minimum amount of hand work for finishing.

Universal Die-sinker: A die-sinking machine known as a universal type, is so designed that both cherrying and straight die-sinking operations can be performed without any changes of set-up or any special attachments. The principal feature of the machine is an oscillating head by means of which an ordinary die-sinking cutter can be moved through a circular path, so that both roughing and finishing cherrying operations can be performed. A double binder provides for locking the entire oscil-

lating head solidly to the column when the machine is to be used for ordinary die-sinking cuts in which the table elevating and transverse movements are employed. The machine is of the vertical type and has a knee supported by an elevating screw and sliding on vertical ways on the column. This knee carries a table which travels in both directions. The oscillating head is moved entirely by hand, through a handwheel on the front of the head. This machine will perform many types of cherrying cuts that are impossible on previous styles of the machine. For instance, by combining the rotary table feed and the oscillating cutter movement, it is possible to sink a spherical cut in the surface of a die and finish it ready for the polishing operation, all with the same cutter and without the use of an attachment.

Die-Sinking, Hub Method. See Hub Method of Die-sinking.

Die-Sets. A die-set consists of a punch holder, base, and pillars or guides for accurately holding the upper and lower members in alignment and as a complete unit which may readily be applied to a press. Die-sets of this general type are manufactured in different sizes. They are so arranged that the user merely equips the die-set with whatever punches and dies or die openings, are required for a given operation.

Die Slotters. The openings in blanking dies are often machined in slotters especially designed for work of this class. A die slotter which represents a typical design is equipped with a short-stroke ram which can be set at an angle with the work table for machining the required amount of clearance. The table is circular and can be rotated for slotting circular openings. This circular table is mounted on compound slides which provide lateral and transverse feeding movements. The machine is of the column-and-knee construction, thus providing vertical adjustment for the work table. Blanking dies are also slotted on an ordinary column-and-knee type milling machine, by using a slotting attachment.

Dies, Sectional Type. Certain advantages are claimed for the sectional stamping die over the solid die. In making repairs on dies of this type, it is only necessary to remove the damaged section and replace it with a new part. Other things being equal, this is a decided advantage. Furthermore, difficulties encountered in hardening a large solid die-block are not met with in the case of the sectional die; and each section can be accurately ground and fitted after hardening, thereby correcting errors due to distortion in hardening. In this way, each section can be made identical with every other. The accuracy that can be obtained in making sectional dies is also of importance.

Sectional dies are used extensively in the production of armature laminations for electric motors and generators, and are also

applicable to the manufacture of other classes of stampings containing a large number of perforations. The only essential difference in design between the sectional lamination die and the solid die is that the punch holes in the sectional die are formed by sections arranged radially and accurately fitted and assembled on a plate.

Die Steel, Cold-Drawing. See Wortle Steel under Tungsten Steel.

Dies, Thread-Cutting. Most external screw threads are cut by means of dies, because tools of this class not only cut threads rapidly but, when properly made, are capable of producing screws that meet most commercial requirements as to accuracy. Dies may be divided into two general classes, namely, those that are removed from the screw thread by being backed off or unscrewed. and those that may be opened so that the cutting edges clear the screw thread, thus permitting the die to be removed by traversing it over the work in a lengthwise direction.

The *non-opening dies* are capable in some cases of hand adjustment, but the object of this adjustment is to vary the size of the die. There are four types of non-opening dies in common use, which may be designated as (1) solid dies, or those that are rigid and incapable of any adjustment for varying the diameter; (2) flexible dies, or those that are split in one or more places and may be adjusted to some extent by compressing or expanding; (3) sectional dies, or those formed of two adjustable sections; (4) rigid adjustable dies of the chaser type, having inserted chasers that may be adjusted radially within certain limits either for maintaining a standard size or for varying the size slightly.

Self-opening Dies: The different designs of *automatic* or *self-opening* dies differ principally in regard to the mechanism for opening the die-chasers at the completion of a cut, the method of closing the chasers to the cutting position after removing the die, and the method of supporting the chasers against radial thrusts. Self-opening dies, in general, are formed of two main sections. One section, which includes the shank and inner part of the die body, is attached to the turret, spindle, or other part of the machine. These two main sections have a certain relative motion for opening the die or releasing the chasers from the work and for closing the chasers to the working position. This motion for operating the die may either be parallel to the axis of the die, rotary, or helical.

Die Taps. Die taps, also known as "long taper die taps," are used for cutting the thread in a die in one single operation from the blank and are supposed to be followed by a hob tap. The die tap is provided with a long chamfered portion and a short

straight or parallel thread. If it is to be followed by a hob tap, the parallel portion should be slightly under the standard size so as to leave enough metal for the hob tap to remove to insure the correct size of the die. This difference in size should not only be on the top of the thread but in the angle of the thread as well, so that any inaccuracy in the lead of the thread may be taken care of. The difference must be very slight, as the hob cannot remove very much stock, as it has a very short chamfer and very small chip room for the stock removed. If this is not taken into consideration, the dies may be injured in the sizing operation. Die taps are very similar to machine nut taps and are made almost exactly in the same way.

Dietzel Process. The Dietzel process is an electrolytic refining process for separating silver and copper, the process consisting in dissolving both of the metals (as anode) in a weak acid solution of copper nitrate. This solution is then transferred to another vessel and the silver is precipitated by metallic copper, after which the copper is deposited electrolytically.

Differential Accumulator. A hydraulic accumulator consisting of two cylinders of different diameters. The smaller cylinder is contained in the ram or plunger that fits into the larger cylinder. By the use of this machine very high pressures can be obtained.

Differential Back-Gears. See Back-gears of Differential Type.

Differential Block or Hoist. See Hoist.

Differential Brake. A differential brake is a band brake in which both ends of the brake band are attached to arms on the brake lever, these arms having different lengths, so that the tension of the brake band can be varied by the operation of the lever. This brake is a good holding brake, but is not as suitable for regulating the lowering speed of a load as is a single-acting brake, because it is liable to give a jerky lowering action.

Differential Gearing. This term is sometimes applied to planetary gear mechanisms, because of the differential motion or difference in the original motions which results in the final motion desired.

One of the important applications of differential gearing, at the present time, is found on automobiles. The object of transmitting motion from the engine to the rear axle through differential gearing is to give an equal tractive force to each of the two wheels and, at the same time, permit either of them to run ahead or lag behind the other as may be required in rounding curves or riding over obstructions. The axle is not formed of one solid piece, but motion is transmitted to the right- and left-

hand wheels by means of separate sections, the inner ends of which are attached to different members of the differential mechanism.

Differential Indexing. See Indexing.

Differential Mechanism on Gear-Hobbing Machines. In cutting helical gears on hobbing machines without a differential, the required ratio which combines index and feed gears must be calculated with considerable accuracy as otherwise a serious error will result which will impair the accuracy of the gears. It frequently happens that the required ratio consists of prime numbers, especially when cutting right- and left-hand gears with one hob. To produce correct helical gears with their axes located parallel to each other, the errors for the right- and left-hand spirals must be the same, otherwise there will not be a bearing on the whole length of the teeth. If the hobbing machine has a differential, it is not necessary to have a right- and left-hand hob for cutting any angle up to 30 degrees; on the contrary, better results are obtained by using only one hob for both right- and left-hand spirals because if there is any distortion in hardening, the right-hand hob will be different from the left-hand.

If the machine has a differential mechanism there is no variation in the helical movement when the number of teeth is increased or decreased or the feed is changed. On machines not provided with a differential mechanism, gears of the same pitch but with different numbers of teeth, must be calculated for separately, and the slightest change in the feed will require a separate calculation. A change in the formula must also be made, if right- and left-hand gears with the same number of teeth are cut with one hob. The differential is also of importance when cutting worm-gears with a taper hob. The belief of many mechanics that the ratios and errors obtained by formulas are alike for all hobbing machines, with or without differential mechanism, is entirely erroneous. There is a great difference between the two ratios. In the one case the ratio represents the value of the indexing and the helical movement, and the slightest change of the "driver," *viz.*, numerator, will cause a great error if the "driven," *viz.*, denominator, is not also changed in the same proportion. In the other case, *i.e.*, with the differential, the ratio obtained refers to the angle or helical movement only, and adds or subtracts itself automatically to or from the ratio of the indexing gears.

Differential or Floating Levers. Differential levers are utilized in some mechanisms to control, by the application of a small amount of power, a much greater force, such as would be required for moving or shifting heavy parts. These levers are commonly ap-

plied to mechanisms controlling the action of parts that require adjustment or changes of position at intervals varying according to the function of the apparatus subject to control. The initial movement or force may be derived from a hand-operated lever or wheel, and the purpose of the differential or floating lever is to so control the source of power that whatever part is to be shifted or adjusted will follow the hand-controlled movements practically the same as though there were a direct mechanical connection. A floating lever is so termed because it is not attached to fixed pivots and does not have a stationary fulcrum, but is free to move bodily, or to "float" within certain limits and in accordance with the relative forces acting upon the different connections.

Differential Wage System. See Wage System, Differential.

Dilatometer. A dilatometer is an apparatus for indicating and recording the volumetric changes in steel while it is subjected to heat, in order to determine correct hardening temperatures. The physical properties of steel, such as hardness, tensile strength, elastic limit, and elongation, are affected by internal physical changes. When heat is applied to a piece of steel it expands due to changing of the internal physical constituents. By measuring the steel while being heated, the dimensional changes serve as a guide to what is taking place within the steel.

The most important critical transformation is that which occurs just before a piece of steel is ready for quenching to obtain full hardness. This is called decalescence, and its presence has been noted by loss of magnetism and by a cessation in the heating rate. Decalescence may be noted by measuring the volumetric changes. The mechanical means of measurement is known as the dilatometric method. This method is said to be very accurate because it measures the changes throughout the mass of the metal.

Dimensioning Drawings. According to drafting-room practice as approved by American Standards Association, dimensions of parts that can be measured or that can be produced with sufficient accuracy by using an ordinary scale should be written in units and common fractions. Parts requiring greater accuracy should be dimensioned in decimal fractions. Dimensions up to and including 72 inches should preferably be expressed in inches, and those greater than this length, in feet and inches.

Where dimensions call for accurate machining with small tolerances it is recommended that the total dimension be given in inches and decimal fractions. In structural drawing all dimensions of 12 inches and over should be expressed in feet and inches. In automotive, locomotive, sheet metal and some other practices all dimensions are specified in inches.

The symbol (″) is used to indicate inches and common and

decimal fractions of an inch. When all dimensions are given in inches the symbol is preferably omitted. A note may be placed on the drawing stating that all dimensions are given in inches. The symbol (′) is used to indicate feet and fractions of a foot. Dimensions in feet and inches should be hyphenated, thus 4′-3″; 4′-0½″; 4′-0″.

Fractions should be written with the division in line with the dimension line.

Dimension Lines and Extension Lines: Dimension lines should be fine full lines (broken where dimension is inserted) so as to contrast with the heavier outline of the drawing, and should be placed outside the figure or drawing outline wherever possible.

Extension lines indicate the distance measured when the dimension is placed outside the figure. They are made as light full lines starting 1/32 to 1/16 inch away from the outline and extending about ⅛ inch beyond the dimension line.

A center line should never be used as a dimension line. A line of the piece or part illustrated or an extension of such a line should never be used as a dimension line.

Dimension Figures: A dimension line must not pass through a dimension figure. If unbroken lines are used, as is common practice in structural drawing, the dimensions are placed above the line. When fractional dimensions of less than one inch are given, the numerator should be placed above the dimension line and the denominator below.

All dimension lines and their corresponding numbers should be placed so that they may be read from the bottom or right-hand edges of the drawing. All dimensions should be placed so as to read in the direction of the dimension lines.

When there are several parallel dimension lines the figures should be staggered to avoid confusion. Dimensions should be given from a base line, a center line or a finished surface that can be established readily. Over-all dimensions should be placed outside the intermediate dimensions. In dimensioning with tolerances, if an over-all dimension is used one intermediate distance should not be dimensioned.

In dimensioning angles an arc should be drawn and the dimension placed so as to read from the horizontal position. An exception is sometimes made in the dimensioning of large areas when the dimensions are placed along the arc.

Dimensioning Circles: A dimension indicating the diameter of a circle should be followed by the abbreviation "D" except when it is obvious from the drawing that the dimension is a diameter. The dimension of a radius should always be followed by the abbreviation "R." The center should be indicated by a cross or circle and the dimension line have one arrow-head.

Dimensioning Holes: Holes which are to be drilled, reamed, punched, swaged, cored, etc., should have diameter, given preferably on a leader, followed by the word indicating the operation, and the number of holes to be so made. Holes which are to be machined after coring or casting should have finished marks and finished dimensions specified.

If needed by the shop on account of the method of laying out, as in the button method, the chordal distances between holes on a bolt circle or the center-to-center distances between holes located by coordinates, should be calculated and dimensioned in decimals.

Dimensioning with Tolerances: Accurate dimensions which are to be established with limit gage or micrometer should be expressed in decimals to at least three places and the drawing should give the maximum and minimum limits between which the actual measurements must come. For *external* dimensions the maximum limit is placed above the line and for *internal* dimensions the minimum limit is placed above the line. This method should be used for smaller parts and where gages are extensively employed.

A second method, used for larger parts and where few gages are employed, is to give the calculated size to the required number of decimal places, followed by the tolerances plus and minus, with the plus above the minus, as $8.625\text{D}\ {}^{+.000}_{-.002}$

Changes in Dimensions: On a drawing, if a dimension must be changed, the changed figures should be underlined or otherwise marked. It is customary to note changes in dimensions in a tabulation on the drawing and to refer to them by letters or smybols placed after the altered dimensions.

Dimensioning Tapers: At least three methods of dimensioning tapers are in general use.

Standard Tapers: Give one diameter or width, the length, and insert note on drawing designating the taper by number.

Special Tapers: In dimensioning a taper when the slope is specified, the length and only one diameter should be given or the diameters at both ends of the taper should be given and length omitted.

Precision Work: In certain cases where very precise measurements are necessary the taper surface, either external or internal, is specified by giving a diameter at a certain distance from a surface and the slope of the taper.

Dinking Die. A dinking die is used for cutting out formed shapes from leather, cloth, or paper. It is, practically speaking, a hollow punch or cutter having a sharp cutting edge shaped to correspond with the contour of the part to be cut. Dinking dies may be used either in a press or may be driven through the

material to be cut by a mallet. The body of a dinking die is usually made of high-grade iron and the cutting edge, which should be of high-grade tool steel, is welded to the body. The outside bevel which forms the sharp cutting edge should have an angle of about 20 degrees. A good block for the cutting edge of the die to strike against can be made of seasoned rock maple. This block is laminated or built up of small strips which are glued or bolted together with the grain endwise. A block of this kind will give better results if kept damp by covering it with a wet cloth when not in use.

Dip Brazing. A method of brazing metal parts by immersing them in liquid spelter solder. The spelter is contained either in a cast-iron tank or in a graphite crucible. See Brazing.

Direct Current. A direct current is a unidirectional current; as ordinarily used, the term designates a practically non-pulsating current. A pulsating current is a periodic current the values of which are always positive (or always negative) and thus as ordinarily employed, the term refers to a unidirectional current. A continuous current is a practically non-pulsating direct current.

Direct-Current Compensator. Same as Balancer.

Discard. The term discard as used in steel mill practice and in specifications relates to that portion of an ingot which is rejected to secure in the finished product freedom from piping or other injurious unsoundness and from undue segregation of chemical components. Discard always refers to the top portion of the ingot unless otherwise specified. Occasional specifications for special products require that a certain amount of discard be made from the bottom as well as from the top portion of ingots.

Discharge Coefficient. In fans, the ratio between the actual quantity of air discharged and the theoretical quantity is the discharge coefficient. It may be taken at about 0.8 for the short outlet from a fan casing.

Discharge Rate. In storage batteries, the discharge rate is the number of amperes that a battery will supply continuously for a given time, usually eight hours, three hours, or one hour. See also Storage Batteries.

Discharging Capacity of Pipe. See Pipe Discharging Capacity.

Disconnecting Switches. The term "disconnecting switch" is applied to that class of lever switches which are used for the purpose of isolating oil switches, transformers, and like apparatus, or for sectionalizing bus-bars or transmission lines. Such switches may be of any voltage rating, but generally the name

"disconnecting" is associated with switches of a voltage rating over that where it is safe to operate the switch by means of the ordinary handle; that is, voltages over 650. Disconnecting switches may be divided into two general classes; namely, indoor and outdoor. *Indoor disconnecting switches* for voltages of 1200 or less are mounted on slate bases. For voltages over 1200 and up to and including 3500, these switches are mounted on marble bases, and for all voltages over 3500, they are mounted on wet-process porcelain insulators which are, in turn, mounted on a sheet-steel or other metal base. *Outdoor disconnecting switches* are always mounted on porcelain insulators and of a type such as is used for supporting the line, these insulators being, in turn, mounted on channel-iron bases or some part of the transmission tower, or, in the case of the lower voltages, even on the ordinary wooden cross-arms.

Dished Die. A drop-forging die or any die used in the hammer, is said to be "dished" when the force of the blows it receives causes the central part of the face to sink beneath the level of the remainder of the face. Dishing is usually traceable to a low grade of steel or to improper hardening.

Dish-Pan Idler. This is a type of supporting idler pulley used in connection with belt conveyors for giving the required trough shape to the belt in order that it may retain the material carried by it. The dish-pan idler consists of three pulleys, one smaller in the center, and two larger, having convex spherical surfaces on the inside, mounted at the ends.

Disk Clutch. A common design of disk clutch consists of a set of driving disks and a set of driven disks located alternately, so that each driving disk is between two driven disks. The driving disks may have key slots on their outer circumferences which are engaged by a key on the inner side of a driving drum, and the driven disks may be provided with lugs or key slots on the inner circumference for connection with the driven member.

Both the driving and driven disks of many clutches are metallic and run in oil. Steel disks about 1/16 inch thick are often used. One set of disks may be of bronze, or possibly of sheet copper. One multiple-disk clutch which has been extensively used has alternate disks of steel and phosphor-bronze. These disks have V-shaped grooves instead of being flat, frictional contact being between the angular surfaces. In dry-plate clutches, one set of plates may be faced on both sides with asbestos fabric, or cork inserts may be used. See Clutches.

Disk Grinders. Disk grinding is employed principally for truing plane surfaces by holding the work in contact with a re-

volving abrasive disk. On the *single-spindle disk grinder*, which is the most common type, the work is simply held against the disk by hand or by placing a surface opposite to the one to be finished against an angle-plate on the table of the machine. The table may be at right angles or some other angle to the face of the wheel and fed toward it by manipulating a lever. Special fixtures are also employed for carrying the work to the disk.

The *vertical-spindle disk grinder* has a large disk wheel which revolves in a horizontal plane. In operating this machine, the parts to be ground are simply laid upon the revolving disk and are prevented from rotating with the disk by a cross bar. If the weight of the work is equal to three or four pounds pressure to the square inch of area to be finished, no additional pressure is required, but, in case it is much less than that, the output can be greatly increased by putting an additional weight on top of the work.

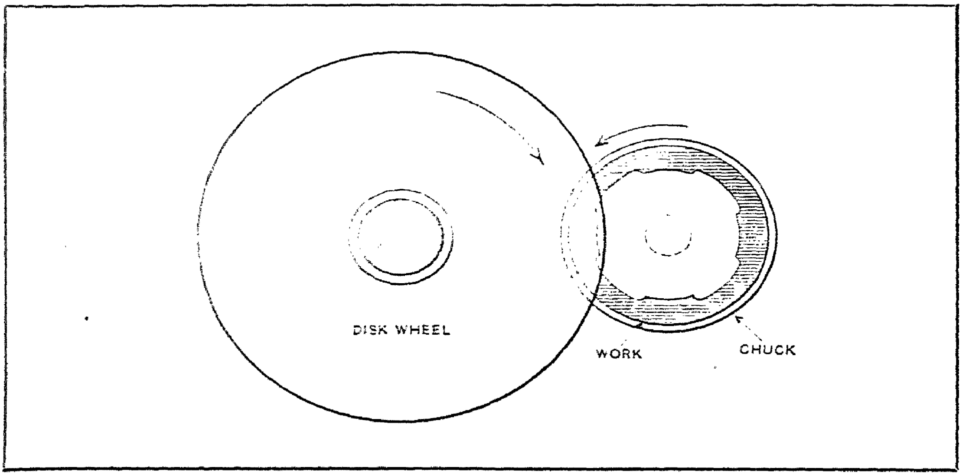
Such operations as grinding parallel sides of piston-rings, wrenches, cap-screw heads, and hexagon nuts are best performed on a *double-spindle disk grinder*. The two spindles are mounted in line, and carry an abrasive disk on the adjacent ends. The piece or pieces to be ground are placed in a work-holding device, advanced between the grinding disks, and ground in some machines by bringing the two disk heads together simultaneously, and in others by advancing only one head, the other one being in a fixed position. The table or work-holding device on both the single- and double-spindle machines is so constructed that an oscillating movement may be given to the work across the face of the grinding disk.

The *automatic double disk grinder* is for finishing parts having two opposite parallel sides of approximately equal area, such as piston-rings, electric iron plates, ball and roller bearing races, and gear blanks. In this machine the work is fed either from a magazine or by the operator into openings in a large continuously rotating wheel which carries the work past the disks.

Disk Grinding Allowances. The amount of stock to be removed, the area of the ground surface, and its distribution are important factors in disk grinding. The removal of from 0.005 to 0.050 inch of stock will usually "clean up" a surface. The following figures, taken from actual practice, represent allowances used in connection with one make of disk grinders: Drop-forged wrenches, from 0.008 to 0.015 inch; brass hexagon nuts, up to 2 inches in diameter, 0.015 inch; larger sizes, up to 0.030 inch; steel punchings, from 0.005 to 0.015 inch; cast-iron machine parts, from 1/32 to 1/16 inch; cast-brass machine parts, from 1/64 to 3/32 inch. The amount of stock that can economically be

removed by disk grinding depends largely upon the nature of the material being ground. Cast metal is more easily ground than rolled or wrought material, and small thin castings are usually harder to grind than larger and thicker castings, owing to the greater density of the metal. When castings have a hard scale, it is often desirable to partially remove it before disk grinding. The hard scale is "broken up" either by grinding on vitrified wheels or by tumbling, sand-blasting, or pickling. The latter method is the best for forgings or hot-rolled material that has considerable scale.

Disk Grinding by Rotary Method. The area that is in contact with the grinding disk is reduced, on some classes of work,



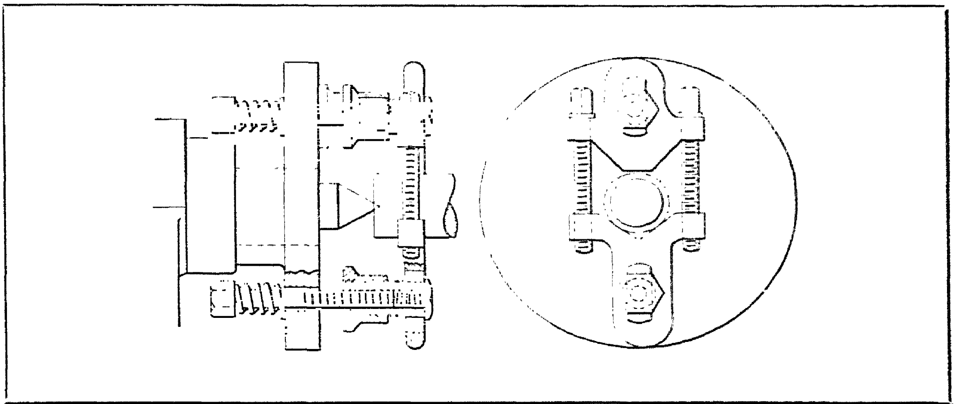
Rotary Process of Disk Grinding

by what is known as the rotary process. The diagram illustrates the principle. The part to be ground is held by means of a magnetic chuck, a faceplate, or a special fixture that is mounted in bearings and is free to rotate. The work table of the disk grinder is located so that the abrasive disk only makes contact with one side of the surface to be ground, as the illustration shows. The action of the grinding wheel rotates the work, so that the entire surface is ground as the result of the rotary motion. The rotary method is employed when the surfaces to be ground are large and unbroken and considerable stock must be removed; when the work is thin and easily heated in grinding, or fragile and easily sprung; and also when an accurate plane surface is required.

Disk Locating Method. Comparatively small precision work is sometimes located by the disk method, which is the same in principle as the button method, the chief difference being that

disks are used instead of buttons. These disks are made to such diameters that, when their peripheries are in contact, each disk center will coincide with the position of the hole to be bored; the centers are then used for locating the work. See also Button Locating Method.

Dividing Engine. A linear dividing engine, which is believed to have been the first automatic machine used in the United States for graduating rules, was invented by J. R. Brown in 1850. This machine was not only fully automatic, but equipped with devices for correcting inaccuracies in the machine itself, such as might develop on account of wear.



Holdback Type of Faceplate Dog

Dividing Head. This is an attachment which forms part of the equipment of all milling machines of the universal type and of many machines of the plain type. It is also known as an indexing head and has index centers since the work usually is held between the centers of the head and a footstock. See Indexing Attachments.

Dogs or Drivers. When a part is held between the centers of a lathe for turning, it is rotated by a dog or driver which is secured to one end of the work and engages a slot in the lathe faceplate. These drivers are also used for operations other than turning, in order to transmit motion from a rotating member to the work; for instance, when a piece is held between the centers of the dividing head of a milling machine, a dog is used to connect the work with the dividing-head spindle, thus rotating the part either when indexing or for generating a helical groove. Dogs or drivers are also used on cylindrical grinding machines for rotating parts held between the centers, and for many other

purposes. To minimize the danger incident to the use of the ordinary lathe dog with its unguarded set-screw which tends to catch in the clothing, especially when filing, many safety dogs have been designed. See Equalizing Dog; also Compensating Dog.

Hold-back Dog: The form of dog here illustrated is intended for driving a part when the outer end cannot be supported by the tailstock center of the lathe, as, for example, when boring a hole in the end of a cylindrical piece one end of which is supported on the headstock center and the other end in a steadyrest. This dog has two bolts which pass through the faceplate. These bolts are supported by spiral springs at the rear of the faceplate, which give the required flexibility and permit the bolts to be so adjusted as to draw equally on both ends of the dog.

Dolomite. Dolomite is a natural carbonate of calcium and magnesium generally used as a flux in blast furnaces and in the basic Bessemer process. Dolomite, like other fluxes, must form with the gangue an ash and slag that will melt at about the same temperature as the iron, which will become fluid enough to be drawn off, and rich enough in lime for the desulphurizing reaction.

Domite. Nickel-alloy cast iron from which it is possible to cast die members to such close dimensions that punches and dies will fit within small fractions of an inch, even without filing. Dies cast from Domite have been found to produce at least 30,000 stampings before redressing was necessary. Used for drawing and stamping dies for automobile fenders, hoods, running boards, hub caps, and accessory parts. Labor in making dies has been reduced greatly by the use of this cast iron.

Double-Action Die. See Drawing Dies.

Double-Action Presses. The double-action type of power press is extensively used for drawing cylindrical or other circular shaped parts from flat sheet-metal stock. There are two slides which are operated independently; hence, the name *double action.* The outer slide is for operating the combined blanking die and blankholder of the double-action drawing die, whereas the inner slide operates the inner plunger or die which draws the part to shape. These slides may be actuated either by cranks, cams, or a toggle mechanism. The presses having a crank form of drive are much used in the manufacture of seamless drawn articles of comparatively shallow depth. The crank type of construction permits of much faster and smoother operation than is practicable with cam-driven presses.

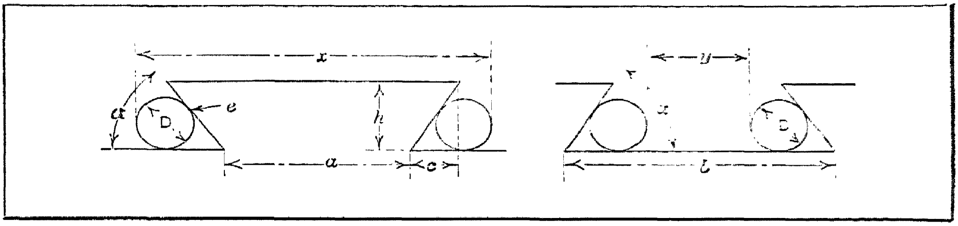
Double-drawing presses differ mechanically from the ordinary double-action press in having three instead of two moving slides,

and, therefore, might appropriately be called triple-action presses. The principal reason for this design is to save time and increase production by making two drawing operations on a single article with one stroke of the press or to draw and redraw, or redraw twice, in a single operation. This type is particularly adapted for articles that require more than one drawing operation to reduce them to the required dimensions.

Double-Contact Cam. A cam in which the follower has two points of contact, one on each side of the cam. This provides a positive motion for the parts connected to the follower.

Dovetail Joint. See Joints used in Patternmaking.

Dovetail Slide. This is a type of slide used extensively in machine construction. It has angular sides which interlock with the grooved part of the mating base or slide. As a general rule,



Cylindrical Rod Method of Measuring Dovetail Slides

a gib is inserted between the slide and the grooved member, to provide means of taking up all play.

Dovetail slides which must be machined accurately to a given width are commonly gaged by using pieces of cylindrical rod or wire and measuring as indicated by the dimensions x and y in the accompanying illustration. In order to obtain dimension x for measuring male dovetails, add 1 to the cotangent of one-half the dovetail angle a, multiply by diameter D of the rods used, and add the product to dimension a. To obtain dimension y for measuring a female dovetail, add 1 to the cotangent of one-half the dovetail angle a, multiply by diameter D of the rod used, and subtract the result from dimension b.

Dovetail Slide Angles. The angle a (see illustration accompanying preceding paragraph) does not conform to any fixed standard and varies in practice, usually from 45 to 60 degrees. The 60-degree slide or dovetail is easier to make and fit accurately than a smaller angle, such as 45 or 50 degrees, and consequently, the 60-degree slide is preferred by most manufacturers. Any wedging action tending to open a dovetail slide, is greater with the 60-degree angle than with smaller angles, the ratio being

173 to 100 for 60-degree and 45-degree slides, respectively. A 45-degree slide, however, requires greater width when properly designed than a 60-degree slide, which usually is important since the slide width is somewhat limited. Within given limits a stronger 60-degree slide can be designed than one of 45 degrees, and the somewhat greater wedging force tending to open the 60-degree slide is ordinarily of little practical importance.

Dowel Pins. Dowels are used either to retain parts in a fixed position or to preserve alignment. Under normal conditions a properly fitted dowel is subjected to shearing strain only, and this strain occurs only at the junction of the surfaces of the two parts which are being held by the dowel. It is seldom necessary to use more than two dowels for holding two pieces together and frequently one is sufficient. For parts which have to be taken apart frequently, and where driving out of the dowels would tend to wear the holes and thus loosen the dowel, and also for very accurately constructed tools and gages which have to be taken apart, or which require to be kept in absolute alignment, the taper dowel is preferable. As applied to average machine work, the taper dowel is most commonly used but the straight dowel is given the preference on tool and gage work, except where extreme accuracy is required, or where the tool or gage is to be subjected to rough handling, and knocking about would be likely to shift the doweled parts.

Dowels, Embossed. See under Rivets, Cold-formed.

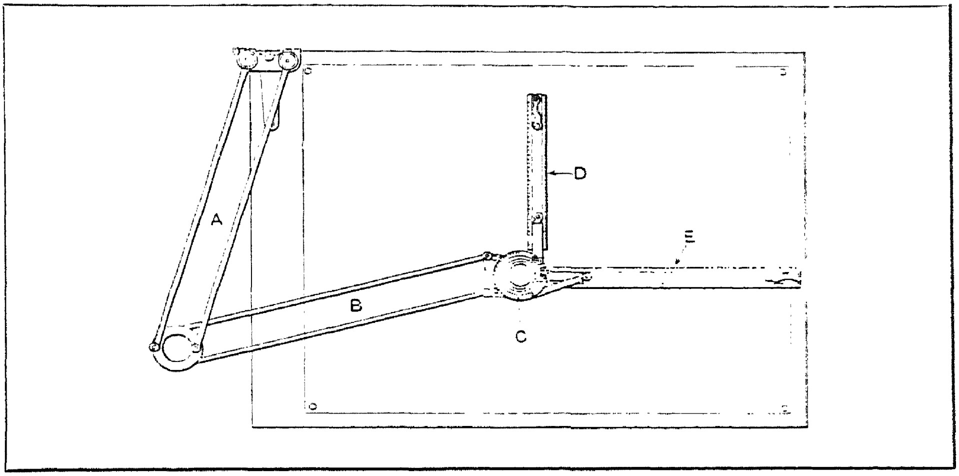
"Dowmetal" Alloys. This is a trade name applied to magnesium alloys. See Magnesium Alloys.

Doyle Rule. The Doyle rule which follows is employed for finding the board measure of logs: Deduct 4 inches from the diameter of the log, square one-fourth of the remainder, and multiply the result by the length of the log in feet; usually the diameter inside of the bark at the small end is measured.

Draft. See Forced Draft; Induced Draft; Mechanical Draft.

Drafting Machines. The device known as a *drafting machine* is employed to facilitate the making of drawings, by taking the place of T-square, triangles, protractor, and scale. It consists of two parallelograms *A* and *B* (see illustration), a protractor *C*, and two scales *D* and *E*, set at right angles to each, these scales being used as ruling edges. The two parallelograms are joined together in such a way that when the upper end of one of them is fastened to the drawing-board, as indicated, the protractor and ruling scales will have a parallel motion on the drawing. This arrangement permits the zero of either of the ruling edges to be instantly placed on any point of the drawing, so that lines may

be drawn and measured off at the same time. The protractor, placed where the two scales or rules join, permits the square formed by the rules to be set at any angle, and after that the ruling edges may be moved about the board with the same parallel motion as when set as shown in the illustration. This feature is of great importance in structural work, where a great many parallel lines must be drawn at angles other than horizontal or vertical. Drafting machines are made for practically all kinds of applications, and for both horizontal and vertical drawing-boards.



Universal Drafting Machine

Draft on Patterns. Draft is a tapering of all the vertical faces of a pattern to permit its removal from the sand without excessive rapping on the part of the molder. There is no rule fixing the amount of draft to give a pattern, but it is a good plan to allow as much draft as possible without distorting the pattern; this may vary from 1/32 to 3/16 inch or may even be as much as 1/4 inch per foot of height. The draft always extends away from the pattern face, or larger side of the pattern. Very small patterns and those of larger sizes to be used in molding machines are often made without draft.

Draw-Bar Pull. This term applied to locomotives represents the amount of power actually exerted at the draw-bar, and it is somewhat less than the tractive force. See Tractive Force.

Draw-Benches. Two types of machines are generally used for drawing shafting and screw stock. The first of these is known as the "straight draw-bench," on which a straight rod is drawn through the die by means of tongs on a head which travels in a

straight line along the draw-bench, power being furnished by an endless sprocket chain or by hydraulic pressure. The second type is the bull-block machine, on which the rod is in the form of a coil that is carried on a reel at one end of the machine; the end of this rod is pointed and threaded through the drawing die, and gripped by tongs carried on a second reel, which rotates in such a way that the rod is drawn through the die and wound up on the second reel.

The draw-benches, by means of which the tubes are drawn, are of different sizes for working on heavy or light stock. The mechanism of the draw-bench is simple and powerful. A typical design that handles tubes up to 20 feet in length consists of a "bench" about twenty-five feet long, within which is an endless sprocket chain of very heavy pattern that passes over a sprocket at the driving end and an idler at the head of the machine. The drive is through compound gearing to the sprocket at the end of the draw-bench, and the sprocket chain runs continuously. The speed at which the chain travels is about sixty feet a minute for the smaller sized machines, but slower in the larger machines. At the forward end of the machine, the frame runs into a very heavy head, against which the dies are held when drawing the tubes. Supported centrally in the head is a steel plate with a clearance hole large enough for the tubes to pass through. Directly against this clearance plate, the dies are held loosely while the tubes are pulled through them. This drawing operation is accomplished by a carriage, drawn away from the head of the machine by means of a hook that may be caught between the chain links. On the forward end of this carriage is a pair of gripping jaws that catch the end of the tube when it is started and pull it through the die. At the end of the stroke, the hook is lifted out of the chain and the carriage returned by hand.

Draw-Filing. When a file is held at each end and the motion is sidewise rather than in a lengthwise direction of the file, this is known as *draw-filing*. With this method of filing, the metal is removed more slowly than by cross-filing, provided the same kind of file is used in each case. The surface is left smoother, however, if the draw-filing is properly done, as the scratches are closer, owing to the shearing cut taken by the file teeth.

Draw-In Chuck. This is a collet type of chuck generally used on tool-room lathes, turret lathes, bench lathes, and similar machine tools, for holding bar stock or tools. The end of the chuck is split so that it can be forced together, to clamp over the stock or tool held in it. The outside of the end is conical, and fits into a conical chuck closer, so that by pulling back the chuck, the chuck closer forces the split chuck to clamp.

Drawing Dies. Drawing dies are used for drawing parts from flat stock into cylindrical and various other shapes. There are several different classes of drawing dies, including plain drawing dies, combination dies, double-action dies, and triple-action dies. The *combination type* of die is one in which a blanking die and either a drawing or forming die are combined so that the blank is cut out and drawn or formed to shape in one stroke of the press. Owing to the construction, a combination die can be used in a single-action press, or one having a single slide. In most cases, articles made in combination dies are in the form of shallow cups, etc., such as can tops and bottoms, pail bottoms and a variety of similar parts which frequently are not over 1/4 inch in depth. Dies of this class are also used for deeper articles, such as boxes and covers for blacking, salve, tobacco, etc., with depths up to about one inch.

Double-action dies are so named because the blanking and drawing punches have independent movements which are derived from the two slides of a double-action press; hence, the name of the die, in this case, indicates the type of press in which it is used. A *triple-action die,* as the name implies, is one having three independent movements. This class of die is used to produce articles requiring three operations, such as cutting or blanking, drawing, and stamping or embossing. Triple-action dies are especially adapted for such work as drawing and embossing lettered covers for blacking boxes, baking powder cans, covers for lard pails, and also for articles such as seamless sardine boxes, etc.

After cups have been drawn in either a plain or double-acting drawing die, what are known as *redrawing dies* are often used to reduce the diameters of these comparatively shallow cups, and at the same time increase the depth or length, thus forming a shell. Some redrawing dies do not differ essentially from an ordinary plain drawing die.

Drawing Sizes. While the practice differs to some extent in different manufacturing plants, it is fairly common practice to use drawings 24 by 36 inches in size as the standard sheet. For smaller work, this is divided into half-sheets, 18 by 24 inches; quarter-sheets, 12 by 18 inches; and eight-sheets, sometimes called "sketching" sheets, 9 by 12 inches. These dimensions of standard sheets have been adopted because it is possible to obtain rolls of drawing-paper, tracing cloth, and blueprint paper in such widths that sheets of the sizes mentioned can be conveniently cut from them without waste.

American Standard Drawing Sizes. Sizes recommended by the American Standards Association for drawing paper and cloth are, in inches: 8½ by 11; 11 by 17; 17 by 22; 22 by 34; 34 by

44. These sizes are based upon the commercial letter size of $8\frac{1}{2}$ by 11 inches, which is in general use in the United States.

Drawing Steel. Steel is "drawn" or tempered by reheating it after hardening to some temperature below the critical temperature range and then cooling the steel. This heat-treatment is often referred to as drawing, but the term tempering is preferable. The object of tempering cutting tools is to reduce the brittleness of the hardened steel and increase its toughness sufficiently to withstand the shocks incident to working conditions. See Tempering.

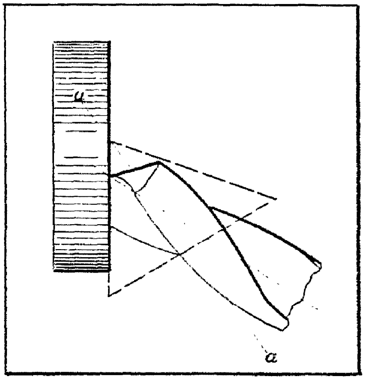
Drill Grinding. As the angle between the cutting edges of a drill is increased, the pressure required for feeding the drill downward through the metal, becomes less, but the length of each cutting edge is increased, with the result that more power is required to turn the drill. An included angle of 118 degrees (59 degrees between the cutting edge and axis) is believed by some to equalize the thrust and torsion to the best advantage, while others advocate more acute angles.

Theoretically, the *clearance* of a drill should be just enough to permit the drill to cut freely, because excessive clearance weakens the cutting edges. The clearance angle often is about 12 degrees at the circumference of the drill when the grinding is done by hand and without a decided increase in clearance toward the point. When soft metal is to be drilled and heavier feeds are possible, the angle of clearance may be increased to 15 degrees, whereas for hard material, such as tool steel, for example, the amount of clearance should be diminished, as a fine feed must necessarily be used and a strong cutting edge is required. These clearance angles of 12 or 15 degrees are much larger than are required at the periphery, in order to increase the angle adjacent to the point which otherwise would have insufficient clearance. With one type of drill grinder, the clearance angle at the periphery usually is about 7 degrees, because special provision has been made for increasing the angle toward the point.

Drill Grinding Machines. Twist drills should be ground in specially-designed drill grinding machines to obtain the best results. The two cutting edges should have the same inclination and come into contact with the work throughout the entire length at the same time, and the clearance surface back of the cutting edge should vary from the point of the drill, where it is greatest, to the periphery, where it is the least acute. A method of obtaining this varying clearance, which is employed in connection with many drill grinding machines, is illustrated by the accompanying diagram. The rotation of the drill, when grinding, is

about an axis a–a which is inclined from the face of the grinding wheel somewhat less than the axis of the drill. When a drill is ground in this way, the end is given a conical surface, the apex of the cone being above the point of the drill, as indicated by the dotted lines.

With one type of drill grinder, the clearance toward the drill point increases at such a rate that 7 degrees, or even less, at the circumference is possible without interference anywhere along the cutting edges when the drill feed per revolution is at the maximum likely to be employed. The object is to obtain maximum support or strength for the cutting edges and also reduce the feeding pressure. In grinding, the drill rotates continuously about its own axis at a constant rate of speed. The drill is held in a two-jaw chuck which is rotated by gearing. This chuck and the drill have a rotary motion. The grinding is done by the flat face of a ring-shaped wheel. The wheel-spindle and wheel have a slight planetary or eccentric motion which imparts to the wheel the equivalent of a traversing movement. The wheel also has an endwise motion governed by a cam. This cam is so shaped and located that the inward motion of the wheel toward the drill starts when a drill lip is horizontal. As the wheel advances, it forms a helical clearance surface on the drill lips. The continued advance of the wheel and the slowing up of the traversing movement at the end of its travel, causes the wheel to form a hollow or concave surface back of the cutting edge adjacent to the point. The result is an increased rake at this part of the chisel point where there is slight cutting, thus reducing the end or feeding pressure.



Drill Grinding

Drill Heads. Single-spindle drilling machines are sometimes equipped with attachments commonly known as *drill heads*, which are equipped with two or more spindles for drilling, simultaneously, whatever number of holes the head is designed for. A drill head of typical construction has a taper shank which enters the drilling machine spindle and drives all of the spindles of the attachment through spur gearing. Drill heads may be divided into two general classes, namely, the adjustable and the non-adjustable types. The adjustable heads vary in regard to the kind or range of adjustment that is possible. The straight-line adjustable drill head has all of the spindles in the same vertical plane, the adjustment in this case enabling the center-to-center distances

to be varied, according to the work. A drill head having radial adjustment is a type of multiple-spindle drilling attachment which may be adjusted for drilling or tapping operations on circles of various diameters.

Drilling Deep Holes. One method of drilling deep holes is to provide a rotary motion for the work and a feed motion for the drill; then if the point of the drill does not run true, it will be carried around by the work in a circle, thus tending to bend the drill in various directions. The drill is by this action forced back into the path of "least resistance," as it is evident that the bending action, being exerted on the drill in all directions, will tend to force the point back in alignment with the axis of the work where there will be no bending action.

Step-by-Step Method: This method involves the use of a hydraulically operated head which automatically feeds the drill to a predetermined depth, withdraws it completely from the hole, and again advances it to a predetermined depth. This cycle is repeated until the hole has been drilled entirely through, or, in the case of a blind hole, to the required depth. With each withdrawal of the drill, the hole is cleared of chips and a copious stream of coolant fills the hole, cooling both tool and work. With this method, drills may be used that have flutes extending only a small fraction of their length and that have thicker web sections than standard drills, therefore possessing greater strength. The depth to which the drill is fed into the work with each forward stroke of the hydraulic head is so controlled that the forward movement is completed before excessive thrusts occur and before the hole becomes clogged with chips. Only a small quantity of chips is produced at each forward drill movement, and it is for this reason that drills can be used having flutes extending only a fraction of their total length and with a thicker web than standard drills. The greater drill rigidity and strength provided by the larger cross-sectional area of the fluted end enables the drills to resist heavy thrusts in any direction.

Generally speaking, the practice is to drill to a depth equal to the drill diameter at each step. This hydraulic method of step-by-step drilling is applicable in the automotive industry for producing long holes of small diameter in crankshafts, connecting-rods, carburetor parts, etc.

Drilling Machines. Drilling machines or "drill presses," as they are often called, which are used for drilling holes in machine parts, are made in many different types designed for handling the various classes of work to the best advantage, and the different types are also built in a great variety of sizes, because the most efficient results can be obtained with a machine that is

neither too small nor too large and unwieldy for the work which it performs. Drilling machines of different designs are classified in various ways.

The *upright drilling machine* is the type most commonly used, and the name applied to this class indicates that the general design of the machine is vertical, and also that the drill spindle is in a vertical position. All drilling machines, however, which have vertical spindles and are arranged vertically, are not classified as upright drills.

The *radial drilling machine,* which is another very common design, has a vertical spindle, which is carried by an arm that may be swiveled about a vertical column. The distinguishing feature of this machine, however, is the radial adjustment of the arm about the column, which adjustment, in conjunction with the traversing motion of the drill-spindle head along the arm, makes it possible to readily locate the drill in any position within the range of the machine, which is a decided advantage when drilling heavy parts that could not be shifted easily. Machines of this class, therefore, are said to be of the radial type, because the radial or swiveling adjustment of the arm is the characteristic feature.

The *sensitive drill* is another vertical or upright design, but it is classified as sensitive because it is a comparatively small machine of light construction, which possesses sensitive qualities which are of value in drilling delicate work.

The *multiple-spindle type,* which is built in both vertical and horizontal designs, is given a name which is self-explanatory. Some drilling machines equipped with multiple spindles are known as *gang drills.* The term "gang drill" is generally applied to a vertical design practically consisting of several machines combined in one unit, and with the spindles all in the same vertical plane. Machines of this general design are also referred to as multiple-spindle drills, by many manufacturers. Drilling machines, however, having spindles which are arranged in a group so that they may be adjusted according to the respective positions of the holes, whether in a straight line, on a circle, or irregular as to location, are especially known as multiple-spindle types.

Some drilling machines having more than one spindle are named according to the number of spindles, as, for example, a four-spindle sensitive drilling machine, etc. In other cases, a special design of machine having several spindles is classified according to the work for which it is intended, as, for instance, a staybolt drilling machine, a locomotive frame drilling machine, a rail drilling machine, etc. Very heavy and powerful drilling machines of the vertical or upright type are also referred to as

"high-duty" or "heavy-duty" type drilling machines, because they are capable of very rapid drilling.

Some drilling machines are equipped with a turret which carries the necessary tools, and is indexed to locate these tools in the working position the same as the turret of a turret lathe. There are two general types of these machines: one has a turret which revolves about a horizontal axis with the tools in a vertical plane, and the other, a turret which revolves about a vertical axis. Machines of this type are adapted to work requiring successive operations, such as drilling, reaming, counterboring, etc.

Drilling Machine Size. The size of an upright drilling machine is equal approximately to twice the distance from the drill spindle to the column. A 28-inch drilling machine, for example, will drill to the center of a 28-inch circle or possibly to the center of a 29-inch circle. The size of a radial drilling machine represents the maximum distance from the column to the center of the spindle or the greatest radius at which the drill spindle can be set.

Drill Press. This term is often applied to metal drilling machines in general, evidently because the drill is pressed or forced through the metal as it revolves. See Drilling Machines.

Drill Rod. Small diameter, high-carbon tool-steel rods are generally referred to as *drill rod.* Drill rod is either polished or unpolished. Carbon-steel drill rod is kept in stock by steel manufacturers in all sizes, from 1/64 to 1½ inches, by 64ths, and, in addition, the standard "letter" and "number" sizes for drills are available. Square drill rod is kept in stock for all sizes between 1/16 and ½ inch, by 32nds. High-speed steel drill rod is kept in stock from 1/16 to ½ inch, by 64ths, and for all "letter" drill sizes, and for "number" drill sizes from 1 to 52, inclusive. Some of the steel manufacturers work to a limit of 0.00035 inch above and below the specified sizes for diameters smaller than 1 inch, and to a maximum limit of 0.0005 inch above or below the specified size, for sizes between 1 inch and 1½ inches.

Drills. A number of different tools used in the machine shop are classified under the head of drills. The most common type of drill for ordinary drilling in solid metal is the well-known twist drill. These drills, as designed for drilling in solid metal, are provided with two grooves or flutes. When a drilled, cored or punched hole must be enlarged, a three-groove drill or a four-groove drill is commonly used. These three- and four-groove drills have flat ends and cannot be used for drilling in solid metal.

In drilling rather deep holes, it may be difficult to supply the point of the drill with the required amount of oil or cutting compound due to the tendency of the chips to carry the fluid back with them before it reaches the bottom of the hole. To overcome this difficulty, oil-hole drills may be used. This type is provided with internal holes or ducts through which the cutting fluid can be carried right to the drill point. The fluid and chips escape through the flutes of the drill in the usual manner.

Drill Shanks: The shank of a drill, or that part which is held in a socket, spindle or chuck, may be either straight (cylindrical) or tapered. If the shank is tapered, it conforms to the Morse standard. Morse standard tapers include eight different sizes ranging from No. 0 to 7. Five or six of these sizes are used for a range of taper shank drill diameters varying from 1/8 inch to 3 or 3½ inches, which is the usual commercial range. This means that each taper number includes quite a range of diameters.

Drill Sizes: There are three methods of designating the sizes of twist drills. In many cases, the actual diameter is given. Numbers are used to represent a certain range of small drill sizes, and a range of somewhat larger diameters is indicated by the letters of the alphabet. Twist drills in fractional sizes are made in a large range of sizes. To illustrate, one prominent manufacturer makes high-speed twist drills in sizes from 1/8 to 1¾ inches varying by 64ths, and by 32nds up to 2¼ inches and then by 16ths up to 3½ inches. In the 26 letter size drills, size A is the smallest and represents a diameter of 0.234 inch. The largest size Z is equivalent to a diameter of 0.413 inch and the difference between consecutive sizes varies from 0.004 to 0.014 inch. In the numbered sizes, the No. 1 size equivalent to a diameter of 0.228 inch is the largest, and the No. 80 size equivalent to a diameter of 0.0135 inch is the smallest.

Sizes of Straight Shank Drills: There are, in general use, four different series of straight shank drills. One series is known as the *taper length* because these straight shank drills have the same total length as the taper shank drills. These straight shank sizes are the same as the taper shank sizes but the range of diameters is somewhat less and usually is from ⅛ to 2 inches.

Straight shank twist drills in the *jobbers length,* or short length, are a small series ranging from 1/64 or 1/32 up to ½ inch in diameter. Straight shank twist drills are also made to conform to both the wire gage sizes and the letter sizes. The letter sizes are also made with taper shanks.

Drill Steels: The steels used for twist drills include plain carbon tool steel, finishing steels, high-speed, and super-high-speed steels.

Carbon Steel: Notwithstanding all of the developments made in tool steels, carbon steel drills fill a definite need and find widespread application. A typical analysis of the carbon tool steel commonly used for drills is as follows: Carbon, 1.20 per cent; manganese, 0.25 per cent; phosphorus, 0.015 per cent; sulphur, 0.015 per cent; and silicon, 0.20 per cent. Some drill manufacturers prefer to add chromium up to approximately 1 per cent. This increases the hardness penetration in the larger sizes and permits of oil quenching in the smaller sizes. Other drill steels contain up to 0.25 per cent of vanadium to add toughness and refinement of grain.

High-speed Steel Drills: Manufacturers of twist drills generally use practically the same analysis of high-speed steel. This analysis is approximately as follows: Carbon, 0.70; tungsten, 18; chromium, 4; and vanadium, 1 per cent. This steel is generally referred to as an 18–4–1 steel. Steels with somewhat over 0.70 per cent carbon are generally used for small drills, while slightly less than 0.70 per cent carbon is used for the larger sizes. The 14 per cent tungsten high-speed steel is no longer used for drills. High-speed steels containing no tungsten, but instead approximately 7 per cent of molybdenum, have given very good results. If the conditions are such that carbon steel drill speeds are sufficient for the purpose, high-speed steel drills are not economical to use, because the difference in performance, as compared with the carbon steel tool, does not compensate for the difference in price.

Cobalt High-speed Steel: By slightly increasing the percentages of carbon and of the alloying metals, and by adding up to 12 per cent of cobalt and 1 per cent of molybdenum, a super-high-speed steel is produced capable of withstanding higher cutting temperatures. There are several cobalt high-speed steel drills on the market that find wide application in drilling hard metals which are beyond the capacity of ordinary high-speed drills. In resisting the action of abrasion, the cobalt high-speed steel drills, with their higher carbon and alloy content, are superior to those made from ordinary high-speed steel, but they cannot be compared with tungsten-carbide tipped tools. The addition of cobalt to high-speed steel increases the red hardness and the resistance to tempering. In other words, cobalt high-speed steel drills can be subjected to higher cutting temperatures without destroying the edges.

Drills, Angular Hole. Special drills have been developed for drilling square, hexagonal, octagonal and other angular holes. Tools for this work have been made in several different forms, but the principle of operation is to rotate a drill of special form in a guide which has the same shape as the hole to be cut. The

drill is mounted in a special floating chuck which allows movement so that the cutting edges of the tool can generate the required shape of hole. The lands of the drill successively come into contact with the guide and act as cams which cause the cutting edges of the drill to follow the desired path. Drills used for this work only cut with the front edges, there being no cutting edges along the side. These angular drills have been used successfully for drilling steel, cast iron, brass, aluminum and various non-metallic substances. Ordinarily, in using tools of this type, it is advisable to first drill a round hole which is about 1/8 inch smaller in diameter than the width across the sides of the square, hexagonal, or other hole. By thus removing most of the metal, the angular drill may be operated at higher speed and with less strain on the tool.

Drill Speeding Attachment. In drilling small holes on a machine which is not arranged for high speeds, the drill revolves too slowly and the operation requires much more time than would be necessary if the drill were operated at the proper speed. Many drilling machine attachments have been designed for increasing the speeds of small drills. These are often called "drill speeders." These attachments are applied to the end of the drill spindle, and, by means of suitable gearing, the auxiliary spindle in which the small drill is held is rotated much faster than the main spindle of the machine.

Drill Speed Regulator. This is an attachment which is applied to the end of the drill spindle for driving different sizes of drills at the correct speed by automatic regulation. A different collet is provided for each size of drill which is used, and the speed changes are obtained by having a driver on each collet located in a different position, so that each one engages the proper gears in the head. With this arrangement, the speed is regulated automatically in accordance with the size of the drill.

Drills, Portable Air-Driven. Pneumatically-operated drilling machines of the portable type are not only used for drilling, but for reaming, tapping, flue rolling, wood boring, and as motors, especially for driving portable tools such as valve-setting and cylinder-boring machines in locomotive repair shops. Pneumatic or "air" drills, as they are often called, are made in reversible and non-reversible designs. The type commonly used is driven by an air motor of the reciprocating piston type, which is contained within the casing of the machine. The pistons are single-acting and impart rotary motion to the crankshaft by suitable connecting-rods. This crankshaft, in turn, drives the main spindle of the machine through gearing which reduces the speed and gives the necessary increase in power. What is commonly known as the

close-quarter air drill is designed for use in corners or narrow places where a drilling machine of ordinary size cannot be used.

Drills, Portable Electric. A portable electric drill is a compact semi-enclosed electric motor in combination with mechanical features so designed and constructed as to be applicable for drilling or reaming in wood or metal more or less intermittently. Portable electric drills are generally listed according to their drill capacity, and sometimes this is definitely specified as the maximum size drill that the motor has sufficient power to drive through steel. Many electric drills have "universal motors" built to operate on either direct or alternating current, the standard frequency for alternating current being 60 cycles, although some of the universal motor types will operate at 25, 30, 40 or 50 cycles, as well. Some drills are built to operate on 180-cycle current for use where a frequency changer is installed and these are claimed to have the advantage of lighter weight as compared with the same sizes in the standard types. Electric drills are made either standard, light duty, or heavy duty, and the weight varies accordingly. Electric drills are equipped with a drill chuck for holding straight shank drills, or a spindle with a standard tapered hole for taper shank drills. The drill chuck or drill spindle is usually driven by reduction gearing from the motor armature shaft. These spindles are located so as to provide what is termed straight-line or close-quarter construction, so as to permit the drilling of holes as close to a wall as possible.

Drive Pipe. The name applied to a pipe used in conjunction with a hydraulic ram. See Hydraulic Ram.

Drivers or Dogs. See Dogs or Drivers.

Driving Fit. When a plug or a shaft is made slightly larger than the hole into which it is to be inserted and the allowance is such that the parts can be assembled by driving, this is known as a *driving fit*. Such fits are employed when the parts are to remain in a fixed position relative to each other. The allowance for a driving fit depends upon the length of the bearing surface, the diameter of the hole, the smoothness of the surfaces and the thickness and kind of metal surrounding the hole.

Drooping Characteristic. This is a term used in connection with electrical machinery when the voltage varies inversely with the load.

Drop Forging. Forgings produced in dies by a falling hammer which is lifted by mechanical means and known as a drop-hammer, are called *drop-forgings*. The shape of the forging is cut out or "sunk" into dies, so that often a single blow of the hammer on the dies shapes the heated iron bar to the desired

form. A drop-forging can be produced with a tolerance of 1/32 inch as an ordinary commercial limit for small work, although it is possible, by careful forging and supplemental restriking, and providing the forging is fairly small, to produce work within a few thousandths of an inch. The degree of accuracy possible in drop forging is, however, very seldom realized, and for work within very fine limits it is necessary to have multiple dies; that is, one or more pairs of dies for roughing-out, and one or more pairs of dies for the finishing operations. *String forging* is the most economical way of drop-forging certain small pieces. By string forging is meant the forming of small pieces in a string, without cutting off each piece separately after forging.

Fin and Flash: Excess stock that is squeezed out of the impression into the narrow space between the upper and lower sections of a drop-forging die, is called the "fin." To take care of this metal that is crowded out of the impression, each die is relieved around the impression by milling a flat, shallow recess, about 1/64 inch deep and ⅝ inch in width all around the impression. These dimensions are for dies of average size; in larger dies, the recess or "flash," as it is called, would be a little deeper and wider. Both the upper and the lower dies are flashed in this manner. In addition, the upper die is back-flashed; that is, there is, a deeper recess, sometimes called the "gutter," milled around the impression at a distance of ¼ inch from the impression at every point. The back-flash is 3/64 inch deep, and acts as a relief for the excess metal after it has squeezed through the flash proper. Only the finishing impression is provided with flash and back-flash. The fin is trimmed from the forging by means of trimming dies, when the forging is either hot or cold, depending upon the size and shape.

Drop-Forging Die Materials. The material from which drop-forging dies are made is usually either a high-grade open-hearth carbon steel or an alloy steel containing certain percentages of nickel and chromium, although other alloys are used in special cases. When drop-forging dies are made from open-hearth steel a 0.60 per cent carbon steel is generally used. In some cases, however, steel as low as 0.40 per cent carbon and as high as 0.85 per cent carbon is used, but few shops use anything but 0.60 per cent carbon steel for the general run of work. If a low-carbon steel is used, a special hardening treatment is required, which outweighs any saving in the price of the steel. The high-carbon steels make good dies, but except in special cases, there is no necessity for using so high-priced a steel. The average 0.60 per cent carbon steel die, if properly hardened, should last for from 15,000 to 40,000 forgings, and sometimes as many as 70,000 forgings are made from one set of dies. In making dies

for large forgings, it is often considered advisable to use 0.80 per cent carbon steel for the dies, and not to harden them. This obviates the danger of "checking" or cracking in hardening, and the steel, unhardened, is hard enough to resist the tendency to stretch.

Special *chrome-nickel steel* has been found particularly suitable for producing drop-forgings from a high grade of material. The development in the use of chrome-nickel steel has been due largely to the demands of the automobile industry, in which there are used a great variety of intricately shaped drop-forged parts made from dense fine-grained alloy steels of various compositions.

Cast-steel dies are sometimes used, but the castings must be sound and free from blow-holes. The advantage of casting the die impressions over sinking them is in the saving of time in manufacture, and more especially in the possibility of producing more intricate shapes. Cast-steel die-blocks are not recommended, however, unless the design of the forging demands that the impressions be cast. On the lighter classes of drop-forgings, particularly if there are only a few to be made from one impression, *cast-iron die-blocks* have been used with fair success. The finest grain of cast iron should be used in making drop-forging dies, and the structure of the iron should be homogeneous.

Drop-Forging Die-Sinking Machines. See Die-sinking.

Drop-Forging Dies, Lead Proof. In making drop-forging dies, it is customary to take a so-called "lead proof" from the impressions in the upper and lower dies, in order to make sure that the forging will have the right appearance when it comes from the dies, and to ascertain that there are no defective places in the impression. In making a lead proof, the impressions of both the upper and lower dies are cleaned and dusted with powdered chalk, the dies placed on end and clamped together with large C-clamps, and the heated lead slowly and evenly poured into the dies until it fills the impression and gate. As soon as the lead has cooled, the dies are unclamped and the lead proof removed and examined. The lead proof will show any places on the forging that are not perfect, and, by weighing the lead, it is possible to ascertain the weight of the finished forging. Roughly speaking, two-thirds the weight of the lead proof will equal the weight of the finished forging. The shrinkage of lead is practically the same as that of steel, so that the finished forging will have practically the same dimensions as the lead proof.

Drop-Forging Steel. Generally speaking, low-carbon steels are more suitable for drop forging than high-carbon steels, because the latter are more difficult to work, there being a tendency to burn the steel on account of the high temperature to which it must be heated for forging. Nickel steels containing up to

3.5 per cent of nickel with about 0.30 per cent of carbon can be drop-forged with comparative ease. Nickel-chromium steels are difficult to drop-forge, particularly when the chromium content is over 1.3 per cent and the nickel content over 2 per cent, with the carbon content about 0.35 per cent; but these steels are very hard when heat-treated and have a very high tensile strength and elastic limit.

The great value of chrome-vanadium steels for drop forging lies in the fact that they can be very easily forged as compared with nickel-chromium steels. A suitable composition would be 1.2 per cent of chromium, 0.16 per cent of vanadium, and 0.32 per cent of carbon. This steel resists bending, torsional, impact, and vibrating stresses to a remarkable degree. Even the best steel may be ruined in drop forging in any one of three principal ways: 1. By careless treatment, in not carrying out the steel maker's instructions. 2. By incorrect treatment, due to ignorance of the properties of the steel used. 3. By working the steel at a temperature unsuitable for that particular brand of steel.

Drop-Hammers. Drop-hammers are so named because the hammer head is lifted by a power and then dropped upon the work. Hammers of this type are extensively used for producing drop-forgings, and are made in two general types, known as *board* drop-hammers and *steam* drop-hammers. With the former type, the hammer head, in its descent, is acted upon by gravity alone. whereas, in the case of a steam drop-hammer, the force of the hammer blow is greatly increased by the action of steam, which is admitted to the upper side of the hammer piston. In addition to the board and steam drop-hammers, there are what are known as "drop presses" or "drops," which are used for stamping and bending operations in connection with the manufacture of jewelry, silverware, etc. The crank-operated drop-hammer or "Peck lift" was largely used for drop forging in the early days of the industry, but this type is now confined principally to stamping work and the silverware trade.

The first patent containing the basic principle of the *board drop-hammer* was taken out by Goulding & Cheney in 1861, the patent covering a drop-hammer that was lifted by means of a belt or board placed between rolls running in opposite directions. In the operation of a board drop-hammer, the hammer proper is raised by the action of frictional rolls which bear against a board that is attached to the hammer. The action of the hammer is controlled by a foot-treadle which is connected with board clamps. There are two of these clamps, one located at the front and the other at the rear of the board, which serve to hold the hammer in its upper position when the foot-treadle is released. When the foot-treadle is depressed, these board clamps are withdrawn, thus

releasing the board and allowing the hammer to drop. By a greater or less depression of the treadle, variation in the force of the blow may be obtained regardless of the stroke or fall for which the hammer is adjusted. For instance, when the foot-treadle is pushed all the way down, the clamps are entirely released and the hammer drops freely, whereas, if the treadle is only partly depressed, there is more or less friction between the board and the clamps, and the fall of the hammer is retarded a corresponding amount. See also Steam Drop-hammers.

Drop Presses. The type of drop-hammer commonly known as a *drop press* has a base or anvil and two guides or uprights the same as a board drop-hammer, but the hammer proper is lifted by a different type of mechanism. A typical design of drop press is arranged as follows: The "lifter" or mechanism for raising the hammer is a separate unit. The hammer is connected to the lifter by a belt, the upper end of which is attached to a crank. This crank is driven by means of a pawl-and-ratchet mechanism which serves to elevate the hammer and then allows it to drop suddenly. The shaft carrying the ratchet is driven, through suitable gearing, from a shaft at the rear on which belt pulleys are mounted.

One of the advantages claimed for the lifting mechanism operating on the crank principle is that the hammer is started slowly from rest and the elevating speed is gradually increased, which relieves the mechanism from sudden strains, so that it is very durable. The lifter is designed to give a quick, snappy blow, although some of the older types were inferior in this respect. The mechanism is operated in practically the same way as a blanking or punching press, it being tripped by operating a foot-treadle. The height to which the hammer is raised and the force of the blow is regulated by changing the radial position of a crank-pin, which is clamped to a toothed arm that provides fine adjustment and at the same time a firm grip.

Drop presses are extensively used in the manufacture of sheet-metal goods, hardware, cutlery, silverware, jewelry, etc., for bending, forming, and stamping operations. Special designs are also made for stamping or embossing and paneling large sheets of thin metal, such as are used by metallic cornice and ceiling manufacturers.

Drum Cam. A cam consisting of a cylindrical barrel into the cylindrical surface of which a groove is cut for the cam roller. Instead of a groove, the cam surface may be constructed by attaching guiding pieces on the surface of a cylindrical drum.

Drum Controller. This is a hand-operated electric motor controller of the non-automatic type consisting of a revolving

drum carrying segments so arranged as to make contact in a predetermined order with contact fingers. Drum controllers are compact, mechanically strong and simple to operate, and can easily be mounted integral with the motor-driven machinery which they are to control, with the controller handle placed in a position most convenient to the operator. They are designed for starting speed control and reversing service depending upon the type of motor with which they are used. This type of controller is frequently used for machine tools, printing presses, and cranes. See also Commutator Controller.

Drum-Wound Armature. A drum-wound armature for a generator or motor is one which consists of a core on which the conductors are wound in the form of coils which are placed in slots around the periphery of the core. There are two main types: The series drum or wave-wound armature, and the multiple drum or lap-wound armature.

In the original drum-wound armature, the coils were wound around the surface of the solid armature core in contradistinction to the ring type wherein the coil was wound around the shell of a hollow core so that part of the conductors were outside the core and part were inside.

"Drunken" Thread. A "drunken" thread, according to prevalent usage of this expression by machinists, etc., is a thread that does not coincide with a true helix or advance uniformly. This irregularity in a taper thread may be due to the fact that in taper turning with the tailstock set over, the work does not turn with a uniform angular velocity, while the cutting tool is advancing along the work longitudinally with a uniform linear velocity. The change in the pitch and the irregularity of the thread is so small as to be imperceptible to the eye, if the taper is slight, but as the tapers increase to, say, ¾ inch per foot or more, the errors become more pronounced. To avoid this defect, a taper attachment should be used for taper thread cutting.

Dry-Air Pump. Dry-air pumps are used for condenser service and are connected with the condensing chamber in such a manner as to withdraw the air only, and not the water of condensation which is removed by a separate *hot-well pump.* This arrangement makes it possible to use valves designed especially for air and thus maintain a considerably higher vacuum.

Dry Analysis. A chemical analysis performed with dry reagents and the assistance of heat.

Dry Cells. The wet cell type of battery has been replaced largely by the "dry cell" which is more convenient, portable, requires less space, and is cheaper. The dry cell is usually made by

placing a carbon cathode and depolarizing compound inside of a zinc cylinder, which forms the anode. The cathode and depolarizer are separated from the zinc by some absorbent material which is saturated with the electrolyte, usually a solution of sal-ammoniac and zinc chloride; but sometimes the separation is made by mixing the electrolyte with some gelatinous body, which is poured into place while hot and, on cooling, forms a jelly. The top of the cell is then sealed to prevent evaporation. See also Batteries.

Dry Coloring. The term "dry coloring" relates to a method of coloring metals by the use of compounds which are mixed together, forming pastes that are applied with a brush. This paste is allowed to remain a number of hours and is then rubbed off. However, the *wet method*, that is, the process of dipping into a chemical solution, presents many advantages, both as regards economy of time and uniform results.

Dryers, Centrifugal. Centrifugal dryers are used for drying metal articles in connection with plating, japanning, etc., and also for cleaning the products from screw machines or other automatic machines. A centrifugal dryer consists of a perforated pan or basket which holds the work and is revolved usually from 1000 to 1500 revolutions per minute, while heated air is circulated through the parts being dried. One type of dryer has a steam coil for heating the air which is forced through the contents of the basket by a fan or blower. Another type contains an electrically-heated grid for supplying the heated air. The drying pan or basket may be revolved either by belt or a direct-connected motor. The drying operation may require from 2 or 3 minutes up to, say, 5 to 7 minutes, depending upon the nature and shape of the product.

Dry Measure. One bushel (U. S. or Winchester struck bushel) = 1.2445 cubic feet = 2150.42 cubic inches; 1 bushel = 4 pecks = 32 quarts = 64 pints; 1 peck = 8 quarts = 16 pints; 1 quart = 2 pints; 1 heaped bushel = 1¼ struck bushel; 1 cubic foot = 0.8036 struck bushel; 1 British Imperial bushel = 8 Imperial gallons = 1.2837 cubic feet = 2218.19 cubic inches.

Dry Process. In assaying, "dry process" is a method for ascertaining the quantity of metals in ores. The process consists mainly in oxidizing the ores by the agency of heat. It is also known as the pyrometallurgical process.

Dry Sand Core. This is a part of a foundry mold, inserted in the mold cavity in such a way as to form either a hole or a recess in the casting. It is made from coarse sand, free from clay, the sand being mixed with a bond or binder until it is of about the consistency of heavy flour dough, and then baked in a core oven until it is dry and hard.

Ductility of Metals. The ductility of metals refers to their susceptibility of being drawn into wire. The finer the wire that can be drawn from a given metal, the more ductile it is. Of the metals, platinum is one of the most ductile. Next in order, of the more common metals, come silver, iron, copper, gold, aluminum, zinc, tin, and lead. The ductility is closely related to the property of metals known as "elongation."

Duraloy. Duraloy is a trade name applied to chrome iron alloys containing a larger percentage of chromium than ordinary stainless steel, the chromium content ranging from 27 to 30 per cent. This alloy was developed originally for high temperature installations as it resists oxidation at temperatures up to about 2100 degrees F. Duraloy has unusual resistance to most corroding elements and particularly to nitric acid, most of the organic acids and to the acid water found in the coal fields. Castings containing 16 to 18 per cent chromium resist corrosion practically the same as those of high chromium content, but are not satisfactory for high-temperature installations. This alloy is used in the form of castings, forgings, bars, sheets, plates, wire, and fabricated forms. The carbon content depends upon the application and also upon the form of the material. For example, the carbon in rolled products is kept low to insure ductility, and in castings it is varied to give either satisfactory machining qualities or extreme hardness and resistance to abrasion. The strength of duraloy varies with the analysis, treatment, and form, but in general the ultimate tensile strength in pounds per square inch varies from 40,000 to 50,000 for cast products, and from 80,000 to 90,000 for rolled material. The strength at high temperatures can only be determined accurately by tests extending over long periods, because fatigue is a very important factor; however, duraloy has a tensile strength at least of 3500 pounds per square inch when subjected over a long period to 1650 degrees F.

Duralumin. Duralumin is an aluminum alloy which is somewhat heavier than pure aluminum but has practically the strength of steel; hence, this is an alloy of great value where lightness combined with strength is required, as, for example, in the framework construction of aircraft. Duralumin was first made in Germany and developed by A. Wilm and associates, during the years intervening between 1903-1914. Duralumin is non-magnetic, withstands atmospheric influences, and offers unusual resistance to sea and fresh waters. It is only slightly affected by numerous chemicals which readily corrode other metals and alloys and does not tarnish in the presence of sulphurated hydrogen. It takes a polish equal to that of nickel-plated articles and remains bright

without cleaning longer than plated or silvered articles. It is an ideal substitute for aluminum, German silver, brass, copper, and steel when lightness combined with strength is required. Although duralumin is only one-third the weight of steel, heat-treated duralumin forgings approximate mild steel forgings in strength, so that wherever weight is a deciding factor, duralumin is satisfactory for most shapes made by hot-working or forging. Duralumin forgings are especially desirable for reciprocating or moving parts where the inertia due to their own weight, forms a large part of the total stress. Duralumin machines easily and, as it does not corrode, is suitable for use in many places where weight is not the prime essential.

Experiments have been made to determine the electrolytic effect from junctions of duralumin with iron or steel. These were made by riveting duralumin bars to iron plates and then placing them in artificial sea-water. The result was only a slight destruction of the iron and a reduction in the weight of the bars of about 0.23 per cent, so there is no objection to using duralumin and iron junctions in aircraft.

Duralumin Composition and Strength. The chemical composition of duralumin varies within the following limits: Copper 3 to 5 per cent, magnesium 0.3 to 0.6 per cent, manganese 0.4 to 1 per cent, the remainder being aluminum plus impurities. Small quantities of other metals are sometimes added for certain reasons; for instance, chromium may be added to increase the burnishing qualities of the metal. The strength and toughness of duralumin are comparable with mild steel, and are obtained with a specific gravity of about 2.8 as against 7.8 for steel. The melting point is approximately 1210 degrees F., the recalescence point, 970 degrees F., the annealing temperature approximately 680 degrees F., and the coefficient of expansion 0.00001798 per F. degree of temperature. In the annealed form duralumin can be drawn, spun, stamped, and formed into a great variety of shapes, similar to brass and mild steel. The physical properties in this state average: Ultimate tensile strength, 25,000 to 35,000 pounds per square inch; yield point, 22,000 to 24,000 pounds per square inch; elongation in 2 inches, 12 to 15 per cent; Brinell hardness, 57; and scleroscope hardness, 11.

Duralumin in its heat-treated form may be slightly shaped or formed and may be bent cold to 180 degrees over a mandrel having a diameter of four times the thickness of the sheet. Its remarkable tensile strength is here combined with its maximum elongation as follows: Ultimate tensile strength, 55,000 to 62,000 pounds per square inch; yield point, 30,000 to 36,000 pounds per square inch; elongation in 2 inches, 18 to 25 per cent; Brinell hardness, 93 to 100; and scleroscope hardness, 23 to 27. Heat-

treated duralumin forgings have similar physical properties. When the sections of forgings are heavy, it is advisable to lower the minimum tensile requirements to 50,000 pounds per square inch. This will cause a proportional increase in elongation. Heat-treated and hard-rolled duralumin is used where no bending or forming is required. It is a hard, strong, springy metal in this state, and machines and polishes well. Its physical properties in this form average: Ultimate tensile strength, 67,000 to 72,000 pounds per square inch; yield point, 58,000 to 65,000 pounds per square inch; elongation in 2 inches, 3 to 8 per cent; Brinell hardness, 130 to 140; and scleroscope hardness, 39 to 42.

Influence of Heat and Cold: Heat has an important influence on the strength of duralumin, the results of tests indicating that the strength decreases 10 per cent for an increase in temperature of 212 degrees F. and about 20 per cent for an increase of 302 degrees F. The loss in strength increases with the increase of temperature. On first heating the increase in elongation is hardly appreciable, and between 302 and 392 degrees F., it decreases. At 482 degrees F., the elongation becomes the same as at the room temperature. Upon further heating the elongation increases with a rising temperature; consequently, wherever duralumin is exposed to heat, the possible decrease of strength must always be considered. Opposed to this, the influence of cooling on the strength properties is less unfavorable. The strength and elongation increase somewhat with a decrease in temperature.

Duralumin Drop-Forging. Duralumin may be drop-forged in the same dies used for steel. Although the coefficient of expansion of aluminum is twice that of steel, the forging temperature is only one-half, so that dies with a shrinkage allowance for steel are suitable for duralumin. Best results are obtained by modifying the design of the drop-forging to suit duralumin, bearing in mind that duralumin does not flow quite so readily as steel. Owing to the sluggish flow, the dies must also be very smooth. The correct forging temperature is about 900 degrees F. If heated above 930 degrees F., duralumin becomes crumbly, and when drop-forged is likely to disintegrate. The correct forging temperature range, therefore, is important, but may vary from 880 to 920 degrees F.

Duralumin Gears. For a given section, the weight of duralumin is about one-third that of bronze, and for parts produced in large quantities, duralumin is the cheaper of the two metals. Therefore duralumin is an ideal material for worm-wheels, and especially those used in automobile constructions, provided the wearing qualities are satisfactory. The tensile strength and relatively high elastic limit insure a superior tooth strength, while the homogeneous structure and uniform hardness of heat-treated

duralumin forgings insure entire freedom from hard spots, porosity and spongy areas so common in bronze castings, which entail not only a machine loss but uneven tooth wear in service. The data from various laboratory tests on bronze and duralumin worm-wheels may be summarized by saying that tests destructive to duralumin worm-wheels were also destructive to those made of bronze.

An important condition was revealed in tests with worm-wheels made of duralumin, by examining the lubricant used. After long tests with bronze wheels where the oil has not been changed, the oil is found to contain particles of bronze in suspension. This condition is sometimes very marked and is of importance not only as indicating tooth wear but as showing the deterioration of the lubricating value of the oil. Oil heavily charged with metallic particles acts more like an abrasive and less like a lubricant, and therefore is an important factor in the wear of automobile gearing, where the oil is infrequently renewed. When duralumin wheels were used, the charging of the oil with metallic particles was practically negligible.

The different tests point to excellent life for duralumin worm-wheels, unless the wheels are roughened by lack of lubrication or too high a tooth pressure which will injure or destroy any worm-gearing. The same qualities that make duralumin a desirable material for worm-wheels also make this material valuable for other types of gears. It is suitable for this class of work when the pressures are sufficiently within its elastic limit of 30,000 pounds. Where this condition is met, and weight and quietness are desirable, duralumin will satisfactorily replace iron, steel, brass, fiber, fabrics, etc. Where duralumin can be run with steel rather than against itself the best results are obtained. An example of this application is found in the timing gear trains of automobile motors where both long life and quietness are essential. Helical duralumin gears alternated with steel gears have been very successful in service. That duralumin gears when meshed with steel gears are quiet may seem somewhat contradictory since, when struck, all duralumin forgings are resonant; however, quiet operation is obtained and is undoubtedly due to the difference in pitch of the sound vibrations of steel and duralumin.

When duralumin and hardened steel are run together the results are always good. An example of this application was shown by having duralumin connecting-rods running direct on the wrist-pins. A better life was obtained at this point than with bronze-bushed rods of equal bearing area. Comparative tests of bearings made from duralumin and bearings made from babbitt show that for shaft speeds exceeding 700 revolutions per minute and loads over 200 pounds per square inch, duralumin bearings de-

veloped less friction, remained cooler and showed practically no loss in weight under most severe conditions. For lower bearing pressure and slower speeds, babbitt metal was superior.

Duralumin Heat-Treatment. An unusual feature of duraluminum is that after it has been hot-, or hot- and cold-worked, it may be further strengthened and toughened from 40 to 50 per cent by heat-treatment. This heat-treatment is somewhat analogous to the heat-treating of alloy steels and consists of quenching at temperatures below the melting point, followed by an aging process. The increased physical properties are not all produced immediately on quenching, but increase during the subsequent aging.

The final rolling or forging of duralumin may be done hot or cold, according to the character of the work being handled or the shape it is desired to produce. The hot- or cold-worked metal in its final shape shows greatly improved physical properties over the cast ingot, but the full development of its qualities is obtained only by a specific heat-treatment. To obtain this heat-treatment, the metal is heated to a temperature of from 930 to 970 degrees F. for a period of time depending upon the section of the piece, and then immediately quenched. The heating and quenching improve the physical qualities of the metal, but the maximum results are obtained only by a subsequent aging. During the aging period, which takes from one to five days, the tensile strength, hardness, and elongation of the alloy increase considerably. Aging is sometimes accelerated by placing the metal in a hot water bath of a temperature up to 212 degrees F. or in a hot room. The heat-treatment develops properties which have not been obtained in a like degree in any other aluminum alloy. The cast ingot has a tensile strength of from 28,000 to 32,000 pounds per square inch, and an elongation of from 1 to 3 per cent.

When duralumin in its finished state must be subjected to several drawing, forming, or similar operations, it is often found necessary to anneal the sheets between operations in precisely the same manner as with other metals. This annealing should be done at about 660 degrees F. If several drawing operations are to be performed, it may be necessary to anneal the metal between such operations. Annealed duralumin can be heat-treated and the maximum physical properties obtained, no matter what shape or form the metal may be reduced to; conversely, heat-treated duralumin may be annealed. Duralumin may be cold-worked after heat-treatment and aging. This operation produces a hard smooth finish, and materially increases the tensile strength of the metal at the expense of elongation.

Heat-treatment Experiments: In order to ascertain the relation between the heat-treatment of duralumin and its mechanical

properties, the Bureau of Standards made a series of experiments resulting in the following conclusions: When duralumin is rapidly cooled by quenching from temperatures between 250 and 520° C. (482 and 968° F.), and aged thereupon at temperatures from 0 to 200° C. (0 to 392° F.), the hardness and, at least at lower aging temperatures, the ductility increase. The actual values of hardness and ductility thus obtained depend upon the quenching temperature; they increase with that temperature up to about 520° C. (968° F.). In order to develop the best mechanical properties by heat treatment, a quenching temperature should be used as near this as is possible without running risk of burning the metal. In practice it should be possible to quench from temperatures between 510 and 515° C. (950 and 959° F.).

The period of time at which sheet material should profitably be held at the quenching temperature lies between 10 and 20 minutes. Heavier sections such as bars might require more time at this temperature, as the structure of such sections would be coarser. Quenching is best and most conveniently carried out in boiling water. The mechanical properties are better after quenching in hot than after quenching in cold water, and there is less danger of cracking due to cooling stresses.

The best temperature for subsequent aging depends upon the mechanical properties that are desired. For most purposes it will be found best to age at 100° C. (212° F.) for about 5 to 6 days. The greater portion of the hardening effect takes place within this period. Such a treatment develops both high strength and high ductility. If a material having a higher proportional limit but lower ductility is desired, the material may be aged at higher temperatures up to 150° C. (302° F.) for from 2 to 4 days.

Durimet. A nickel-chromium-molybdenum low-carbon steel having corrosion-resisting properties for the handling of corrosive liquids. Used for all parts that come in contact with such corrosive liquids as weak sulphuric and other acids, chlorine bleach solutions, and caustics.

Duriron. Duriron is a hard, white iron silicide, highly resistant to practically all commercial acids. The composition is approximately as follows: Silicon, 14.25 to 14.50; Carbon, 0.60 to 0.80; Manganese, 0.30 to 0.35; Sulphur, under .05; Phosphorus, under .15.

The hardness of duriron is such that it cannot be machined by a cutting tool and must be finished by grinding. Duriron can be used safely in connection with nitric, sulphuric, acetic, and a large list of other commercial acids at practically any concentration or temperature. This is also practically true of cold hydrochloric acid. With hot hydrochloric acid, however, more consideration must be given to the conditions.

Duronze. An alloy of high resistance to wear and corrosion, composed of aluminum, copper, and silicon, with a tensile strength of 90,000 pounds per square inch. Developed for the manufacture of valve bushings for valves that must operate satisfactorily at high pressures and high temperatures without lubrication.

Dust Separators. The function of the dust separator in an exhaust system is to clean the air returned to the atmosphere to the degree of cleanliness which will fulfill the purpose for which the system is installed. Thus, in a system designed to recover valuable wastes, the justifiable thoroughness of cleaning is regulated by the balance between the value of the material collected and the cost of recovery. When abatement of neighborhood nuisance is the principal purpose of a dust collecting system, the air cleaner must remove all or nearly all of the dust particles visible to the naked eye which would otherwise reach the zone of complaint. If the purpose of the system is to eliminate a health hazard, the separator must clean to a degree which will avoid dangerous recontamination of breathing zone air.

Dutch Metal. An alloy of copper and zinc resembling gold. It contains about 80 per cent of copper and 20 per cent of zinc.

Dutch Oven Furnace. The Dutch oven type of boiler furnace is especially adapted for the burning of bituminous coal. The furnace proper is extended in front of the boiler, and at the rear of this is a mixing wall or baffle which gives a hot wall for the burning gases to strike against as they rise from the bed of fuel. This gives the hydro-carbons ample opportunity, after being distilled from the fresh fuel on the grate, to become thoroughly mixed with the air before passing into the combustion chamber at the rear of the wall.

Duty of Steam Pump. See Pump Duty.

Dynamic Balance. When a rotating part is in dynamic or running balance, the effect of centrifugal force on any unbalanced masses has been counteracted sufficiently to meet practical requirements. Dynamic balancing is especially important for rapidly rotating parts, particularly when the length is great in proportion to the diameter so that unbalanced masses may lie in widely separated planes and thus cause excessive vibration. See Balancing.

Dynamic Brake. This is an electric brake used for slowing down and stopping motors driving industrial machinery, especially hoists and cranes. The motor acts as a generator, the generating action causing the motor shaft to absorb mechanical energy from the machine to which it is connected and thereby establish a braking action. Dynamic brakes are generally sup-

plemented by mechanical friction brakes, because the dynamic braking action ceases when the motor comes to rest.

"Dynamic braking" is the term used when power is absorbed in a rheostat, to distinguish it from "regenerative braking" which indicates that the power is returned to the constant voltage power system. A combination of dynamic braking and regenerative braking is used on crane hoists, elevators, reversing planers, etc. Sometimes regenerative braking alone is used on long hoists where the time of lowering is something like one-half of a minute or more. On electric trains traversing steep or long grades the use of regenerative braking results in considerable saving in power and wear on brake shoes and wheels. See Regenerative Braking.

Dynamic Electricity. The term *dynamic electricity* relates to electricity which flows through some kind of a conductor as a current; for example, when the terminals of one or more electrical batteries are connected by means of a wire, a current will flow through the wire from one terminal to another.

Dynamic Pressure. The pressure exerted by a fluid or gas, flowing in a duct or pipe, due to the momentum of the moving fluid in the direction of the flow.

Dynamite. Dynamite is nitroglycerine to which an absorbent has been added in sufficient quantity to form a solid mass, such as diatomaceous earth, clay, ashes, or carbon. It is important that the adulterant have the correct absorbing qualities, for an excess of nitro will naturally exude, while if the absorbent is in excess, it is likely to crumble. Either condition is likely to give serious trouble at some unexpected moment. Both nitroglycerine and dynamite are particularly dangerous, owing to their instability.

Dynamo. The name dynamo is an abbreviation of the longer original name, "dynamo-electric machine," and it is a machine for converting mechanical into electrical energy. The name "dynamo" is not used in the electrical industries today to the extent that it was used in the earlier days of the development of electrical machinery, the name *generator* having, in the United States at least, almost entirely replaced *dynamo.*

Dynamo Invention. The principle of the dynamo was discovered by Faraday in 1831 and demonstrated by him in a simple model consisting of a permanent horseshoe magnet and a copper disk which rotated between the magnet poles. Two circuit contacts were provided, one on the periphery of the disk and one on the spindle. The first dynamo-electric machine which utilized current from the armature, in the coils of the field magnets, was

invented by Hjorth of Copenhagen, and was patented in England in 1855. Although the principle of the dynamo was embodied in this patent, the practical value of such a machine was not appreciated until some time later, and the development of the highly efficient machine now in use has been due to the work of a number of different inventors. Patents for the polyphase or multiphase current type were granted to Tesla in 1888.

Dynamometers. A dynamometer is an apparatus for measuring the power developed, absorbed, or transmitted by any piece of machinery. *Absorption dynamometers* absorb the power generated or transmitted by any mechanism, measuring it during the process of absorption. Dynamometers of another type measure the power by transmitting it through the mechanism of the dynamometer from the apparatus in which it is generated, or to the apparatus in which it is to be utilized. Dynamometers of this class are known as *transmission dynamometers.* Dynamometers known as *indicators* operate by simultaneously measuring the pressure and volume of a confined fluid. Indicators are very seldom used, however, except for the measurement of the power generated by steam or gas engines or absorbed by refrigerating machinery, air compressors, or pumps.

Dynamometers of Electrical Type. An electrical dynamometer is an apparatus for measuring the power of an electric current, based on the mutual action of currents flowing in two coils. It consists principally of one fixed and one movable coil, which, in the normal position, are at right angles to each other. Both coils are connected in series, and, when a current traverses the coils, the fields produced are at right angles; hence, the coils tend to take up a parallel position. The movable coil with an attached pointer will be deflected, the deflection measuring directly the electric current.

Dynamotor. A dynamotor is a direct-current machine which combines both motor and generator action in one magnetic field; it is used for transforming high-voltage direct current into low-voltage direct current, or *vice versa;* hence, it performs the same functions with relation to direct current as a transformer does in relation to alternating current. These machines are used mainly for obtaining large currents for starting other motors, or for giving low voltages or a fractional voltage in a multi-voltage system, for speed control. They are also employed for obtaining a low voltage for telephone and telegraph systems, and for obtaining the low voltage and large currents required for electrolytic work. The dynamotor has an armature with two separate windings and two separate commutators. Either winding may be used as a motor winding and the other as a generator

winding. A dynamotor is smaller, lighter, and cheaper than a motor-generator set, although the latter has the advantages that the high- and low-voltage circuits are absolutely independent, and that there is no fixed relation between the two voltage values.

Dyne. One dyne is the unit of force in the C. G. S. (centimeter-gram-second) system, frequently also known as the *absolute system of measurement*. One dyne is equivalent to 1/981 gram, this value being derived from the fact that the acceleration due to gravity (at Paris) equals 981 centimeters in one second.

E

Earth Circuit. In electricity, an earth circuit is one in which the earth or ground forms the path for the current. Often a metallic circuit is grounded, as, for example, the return circuit for direct-current railways, where the track rails form the grounded return circuit. The negative terminal of the generator should always be connected to the grounded circuit, so as to minimize electrolysis.

Earth Load Capacity. See under Foundations for Machinery.

Earth or Soil Weight. Loose earth has a weight of approximately 75 pounds per cubic foot and rammed earth, 100 pounds per cubic foot. The solid crust of the earth, according to an estimate, is composed approximately of the following elements: Oxygen, 44.0 to 48.7 per cent; silicon, 22.8 to 36.2 per cent; aluminum, 6.1 to 9.9 per cent; iron, 2.4 to 9.9 per cent; calcium, 0.9 to 6.6 per cent; magnesium, 0.1 to 2.7 per cent; sodium, 2.4 to 2.5 per cent; potassium, 1.7 to 3.1 per cent.

Ebonized Monel. Monel metal with an ebony finish obtained through an oxidizing operation. The metal is identical with regular Monel except for the lustrous blue-black finish. It is immune to rust and resists discoloration at relatively high temperatures. Suitable for applications where appearance must be maintained at temperatures up to 1400 degrees F., as in reflectors, deflectors, element pans, etc., of electric heating units.

Eccentric. An eccentric is, in reality, a short crank with a crankpin of such size that it surrounds the shaft. The slide valve of many steam engines is driven by an eccentric attached to the main shaft. The *throw* of an eccentric is equal to the diameter of a circle described by the center of the eccentric as it rotates with the shaft. The travel of the valve equals the throw of the eccentric, unless there is an intervening rocker with lever arms of unequal length; which causes a variation in the movement of the valve. The radius of an eccentric, or the distance from the center of its shaft hole to the center of the eccentric, is sometimes referred to as the *eccentricity*. This radius is sometimes called the throw, although that is generally considered to be an incorrect definition.

Eccentric Gears. In some of the developments in automobile accessories, such as self-starters and speedometers, conditions

exist which require a high velocity ratio in a comparatively small space; this requirement has led to the development of what are commonly known as *eccentric gear combinations*. These combinations are, in reality, planetary gearing consisting either of two gears or of four or more gears.

Echols Thread. Chip room is of great importance in machine taps and tapper taps where the cutting speed is high and always in one direction. The tap as well as the nut to be threaded is liable to be injured, if ample space for the chips to pass away from the cutting edges is not provided. A method of decreasing the number of cutting edges, as well as increasing the amount of chip room, is embodied in the "Echols thread," where every alternate tooth is removed. If a tap has an even number of flutes, the removal of every other tooth in the lands will be equivalent to the removal of the teeth of a continuous thread. It is, therefore, necessary that taps provided with this thread be made with an odd number of lands, so that removing the tooth in alternate lands may result in removing every other tooth in each individual land. Machine taps are often provided with the Echols thread.

Economizer. An apparatus designed to save waste flue-gas heat in power plants is called an *economizer* and consists of a bank of tubes through which the water passes on its way to the boiler. The economizer is usually placed behind a row of boilers and a little above them. Although this heat is commonly used in warming the feed water, the term *feed-water heater* is only applied to devices employing either live or exhaust steam.

Eddy - Currents. Eddy - currents, sometimes also called "Foucault" currents, are irregular electric currents induced in an iron core or other metallic mass along closed paths of least resistance linked with the flux, when the magnetic flux varies in the core. These currents permeate the whole bulk of the core, with a resultant loss of energy in the form of heat. They may be considerably minimized by laminating the core.

Edging Axes. The operation of grinding off the "flash" left on axe forgings is called "edging." The old method of edging axes was by means of sandstone wheels. The forgings were held under pressure against the revolving sandstone, the pressure being exerted by a steel lever bar whose fulcrum was in an adjustable platform in front of the wheel. The old method is still in use but artificial wheels, which have replaced sandstone wheels for other axe grinding operations, are now used in many shops for the edging operation.

Edison Battery. This is an alkaline storage battery in which the active material of the positive plate is nickel hydrate, the

active material of the negative plate is black oxide of iron, and the electrolyte is a solution of potash in water. It is widely used for railway signal systems, electric industrial trucks and tractors, police and fire alarm systems, emergency lighting and other applications where dependability and long service life are important factors.

Edison-Lalande Cell. This is a primary cell or battery in which the anode is amalgamated zinc in the form of two sheets hung at each side of the cathode. The depolarizer consists of cupric oxide in the form of a plate, the surface of which is reduced to metallic copper to form the cathode. The electrolyte is a solution of potassium hydroxide or sodium hydroxide. The cell is used for closed circuits and large currents. The electromotive force is low—about 0.7 volt—but as the internal resistance is also low, the currents are large. The cell may be left unused for several months without evaporation, the electrolyte being covered with a layer of heavy mineral oil for this purpose.

Edison Wire Gage. The Edison wire gage is simply another name given to the circular mil gage system for measuring electric wires. The gage numbers correspond to the numbers of thousands of circular mils of area of cross-section of the wire; hence, a wire, the cross-section of which is 110,000 circular mils, is gage No. 110. The American or Brown & Sharpe wire gage is generally used for electrical wires, and may be considered the standard for this purpose.

Effective Pressure. The effective pressure in the cylinder of a steam engine varies throughout the stroke. The mean effective pressure (M.E.P.) is the average of all the effective pressures, and this average multiplied by the length of stroke gives the work done per stroke. The mean effective pressure may be determined from an indicator card, and it is used in calculating the *indicated horsepower* of an engine.

Effective Pull. The effective pull of a belt is the difference in tension between the tight and slack sides of the belt. The approximate horsepower that may be transmitted by a belt can be determined by multiplying the effective pull in pounds per inch of belt width, by the width of the belt in inches and the speed of the belt in feet per minute, and dividing the product thus obtained by 33,000. The allowable effective pull depends not only upon the kind and quality of the belt, but also upon the operating speed; for example, the effective pull per inch of width for a single-ply belt 3/16 inch thick and of good quality, may be about 65 pounds for a belt speed of 3000 feet per minute, whereas 50 to 55 pounds should not be exceeded for a speed of about 5000 feet per minute.

Efficiency of Mechanism. The efficiency of a machine is the ratio of the power delivered by the machine to the power received by it. For example, the efficiency of an electric motor is the ratio between the power delivered by the motor to the machinery which it drives, and the power it receives from the generator. Assume, for example, that a motor receives 50 kilowatts from the generator, but that the output of the motor is only 47 kilowatts. Then, the efficiency of the motor is $47 \div 50 = 94$ per cent. The efficiency of a machine tool is the ratio of the power consumed at the cutting tool to the power delivered by the driving belt. The efficiency of gearing is the ratio between the power obtained from the driven shaft to the power used by the driving shaft. Generally speaking, the efficiency of any machine or mechanism is the ratio of the "output" of power to the "input." The percentage of power representing the difference between the "input" and "output," has been dissipated through frictional and other mechanical losses.

Mechanical Efficiency: If E represents the energy which a machine transforms into useful work or delivers at the driven end; L equals the energy lost through friction or dissipated in other ways; then

$$\text{Mechanical Efficiency} = \frac{E}{E}$$

In this case the total energy $E + L$ is assumed to be the amount that is transformed into useful and useless work. The actual total amount of energy, however, may be considerably larger than the amount represented by $E + L$. For example, in a steam engine there are heat losses due to radiation and steam condensation, and considerable heat energy supplied to an internal combustion engine is dissipated either through the cooling water or direct to the atmosphere. In other classes of mechanical and electrical machinery the total energy is much larger than that represented by the amount transformed into useful and useless work.

Absolute Efficiency: If E_1 equals the full amount of energy or the true total, then

$$\text{Absolute Efficiency} = \frac{E}{E_1}.$$

It is evident that absolute efficiency of a prime mover, such as a steam or gas engine, will be much lower than the mechanical efficiency. Ordinarily, the term efficiency as applied to engines and other classes of machinery, means the mechanical efficiency. The brake horsepower of a steam engine or energy delivered to the fly-wheel, divided by the indicated horsepower or work done in the steam cylinder (as shown by an indicator card) equals the

mechanical efficiency. This efficiency should be determined at full load. In the case of manufacturing machinery the energy available at the driven or working end divided by the energy supplied to the initial driving shaft equals the mechanical efficiency.

Efficiencies of Different Mechanisms: The efficiency of a given machine or machine element sometimes varies over a fairly wide range. Such variations may be due to different operating conditions, to differences in workmanship, or to variations in the design of a machine or machine element of the same general class; hence, the specific figures which follow are merely intended to serve as a general guide and indicate, as far as possible, efficiencies under average conditions. The efficiencies of ordinary or plain bearings usually vary from 95 to 98 per cent. Roller bearings and ball bearings have efficiencies of about 98 to 99 per cent.

Spur gears with cut teeth and with bearings included have an efficiency of about 96 per cent, whereas bevel gears may have about 1 per cent less, or 95 per cent. Belt drive efficiencies range from 96 to 98 per cent; roller chain drives, from 95 to 97 per cent; and high-class silent chain transmissions, from 97 to 99 per cent.

Egg Coal. Coal in pieces of such size that they will not pass a screen of 2-inch mesh, but will pass a screen of 2¾-inch mesh.

Ehrhardt Process. This is a process of producing seamless tubing in which a piercing bar is forced into a solid billet, the cross-section of which corresponds to the area of the tubing to be made. This billet, heated to a white heat, is placed in a form which corresponds to the outer shape of the tube. The difference between the area of this form and the area of the billet must equal the area of the pierced bar. The metal forced from the center flows to the outside, occupying the space between the original billet and the form, which is equal to the amount of material displaced by the piercing bar.

Ejector Condenser. The ejector type of condenser is so constructed that the exhaust steam from the engine is condensed by mixing it directly with the condensing water. See Condenser.

Ekko Process for Making Molds and Dies. The "Ekko" process is a method of making molds and dies which has grown out of the research conducted by the United States Rubber Co. The process produces the molds and dies by what has been termed "electroforming" of iron against a pattern that is to be reproduced. Electroforming is simply a type of electroplating, except that deposits up to ½ inch thick can be made instead of 0.001 or 0.002 inch as in the usual electroplating processes. Electroplating is mainly used for decorative purposes or to provide corrosion

resistance, while electroforming is used to build up an appreciable mass of metal.

When the heavy electroformed deposits of iron are separated from the underlying pattern, a cavity or die is obtained in which are reproduced the shape and surface finish of the pattern in every detail. This cavity or die, when properly "backed up" or mounted, can be used to mold or stamp objects of the exact shape of the original pattern.

After a mold has been produced by engraving, it can be reproduced as many times as desired by electroforming. The engraved mold is used to mold the pattern, which is later covered with iron by electrodeposition. In the case of tire patterns, the pattern on which the iron is deposited is made of rubber. The pattern is rendered conductive by dusting it with powdered graphite and polishing it vigorously with a light brush. The polishing operation adds to the finish obtained on the electroformed cavity. Patterns on which the iron is deposited may be of wood, glass, or plastics, provided the surface is made conductive to the current, as explained. Metal patterns are also satisfactory, with the exception of those made from zinc or aluminum, which are attacked by the plating bath.

The iron deposited by the process is 99.98 per cent pure, and practically free from porosity. It is about 50 per cent harder than cold-rolled steel; it has a scleroscope reading of 37, and a Brinell reading of 240. The deposited metal can be softened to the normal value for pure iron by annealing. It can also be hardened by carburizing, so that it will scratch glass. Electrolytic iron has a heat conductivity nearly twice that of cast iron or steel. This is of especial advantage in molding operations, where a high rate of heat transfer is desirable.

Elastic Bonding Process. See Bonding Processes for Grinding Wheels.

Elastic Cements. The various cements containing rubber are elastic, if the rubber is in a predominating amount; many containing boiled linseed oil, and the hectograph composition are quite elastic. The rubber and linseed-oil cement, given in the paragraph headed Acid-proof Cements, is very tough and useful for nearly all purposes except when oil vapors are to be confined. The most useful single rubber lute is probably the so-called Hart's india-rubber cement. Equal parts of raw linseed oil and pure masticated rubber are digested together by heating, and this mixture is made into a stiff putty with fine "paper stock" asbestos. It is more convenient, however, to dissolve the rubber first in carbon disulphide, and, after mixing the oil with it, to let the solvent evaporate spontaneously.

Elastic Grinding Wheels. Very narrow grinding wheels are made by the elastic process. Shellac is the principal ingredient in the bond, and the wheels made by this process are strong and have considerable elasticity, so that very thin wheels can be used safely. Wheels 1/32 inch thick are manufactured. Thin elastic wheels are used for slotting and for cutting off stock such as tubing, pipes, wire, thin sheets of tin or brass, and other materials, especially when the parts are difficult to hold for cutting with regular tools. Thicker elastic wheels are employed for saw-gumming, grinding the teeth of gears, sharpening wood-working tools, etc. They are also used for cutlery work and roll grinding, where a very smooth polished surface is desired.

Elastic Limit. When external forces act upon a material, they tend to produce stresses within it. All stresses to which a material is subjected cause a deformation. If the stress is not too great, however, the material will return to its original shape and dimensions when the external stress is removed. The property which enables a material to return to its original shape and dimensions is called *elasticity.* If a material has been stressed to such an extent that, upon the removal of the load, it does not fully return to its original shape and dimensions, its *elastic limit* has been exceeded. Up to the elastc limit, the deformation is directly proportional to the loads. When the elastic limit is exceeded, the extensions in a material under stress cease to be proportional to the loads. The elastic limit can only be determined by the skillful use of very delicate instruments and by the measurements of the extensions for small successive increments of load. It is impossible to determine the elastic limit in ordinary commercial testing. For this reason, the ultimate strength of materials is more commonly used in the calculation of strength than the elastic limit, although the value for the elastic limit is a more accurate measure of the stress-resisting properties of the material, and in all engineering designs, the load applied to the material must never be so great that the elastic limit is exceeded. The elastic limit should not be confused with the *yield point,* which is the point where the extension of a material under test increases without increase of load.

Elbow. An elbow or "ell" is a fitting that makes an angle between adjacent pipes. The angle is always 90 degrees, unless another angle is specified. The name *branch elbow* is used to designate an elbow having a back outlet in line with one of the outlets of the "run." It is also called a "heel outlet elbow." A *double-branch elbow* is a fitting that, in a manner, looks like a tee, or as if two elbows had been shaved and then placed together, forming a shape something like the letter Y or a crotch. A *drop*

elbow is a small-sized elbow that is frequently used where gas is put into a building. These fittings have wings cast on each side. The wings have small countersunk holes so that they may be fastened by wood screws to a ceiling or wall or framing timbers. A *union elbow* has a male or female union at one end. A *service elbow* has an outside thread on one end and is also known as a "street elbow."

Electric Accumulator. The expression "electric accumulator," is seldom or never used in the United States to designate a battery for storing electrical energy, but this term is frequently so used in other English speaking countries. In the United States "storage battery" is the accepted expression.

Electrical Condenser. See Condenser, Electrical.

Electrical Conductors. See Conductor Materials.

Electrical Discharge. Discharge, in electricity, is the equalization of the potential difference between the terminals of a condenser or other source of electricity, on their connection by a conducting medium or as a result of the breakdown of the insulating medium between them. The term also applies to the removal of a charge from a conductor by connecting the same to the earth. *Brush discharge* is a faint luminous discharge which takes place from a positively charged pointed conductor.

Electrical Horsepower Equivalent. See under Horsepower.

Electrical Resistance Standards. Manganin, an alloy of copper, manganese, and nickel, is generally used as a resistance alloy for the wire-wound standards that maintain the unit of electrical resistance in our national standardizing laboratories. The United States Bureau of Standards, however, has found that an alloy consisting of 85 per cent copper, 9.5 per cent manganese, and 5.5 per cent aluminum is superior in several respects for this purpose. Alloys for the use mentioned must be very stable in resistance. When properly baked, coils of wire made from the new alloy show advantages over manganin.

Electrical Sheet Steel. Because of its particular adaptability for use as a core material in magnets, transformers, and motor and generator armatures, a special kind of steel in sheet form which contains from 1/4 to 4 1/2 per cent silicon, is designated as electrical sheet steel. It is used in a large number of different gages to form core laminations which serve to restrict eddy-currents. Sheets with high silicon content (within the above-stated range) have the lowest eddy-current and hysteretic losses, low saturation flux densities, and high permeability, but are somewhat stiff, lacking ductility. They are used for power trans-

formers, distribution transformers, and high-efficiency motors and generators. Sheets with low silicon content, on the other hand, are quite ductile but have less desirable magnetic properties. Because high ductility is important from the standpoint of wear on dies in large quantity production and because some sacrifice in magnetic qualities can be made in the lower grades of motors, such as single-phase fractional-horsepower motors for intermittent duty, this low-silicon steel is widely used. In between these two extremes, various grades are available to meet the requirements of many different kinds of cores.

Electric Arc. An electric arc is the luminous arc formed when a current of electricity passes from one conductor to another through a gas or vapor which has been brought to incandescence by the discharge of electricity. The conductor from which the current passes into the incandescent gas or vapor is known as the *positive electrode,* while the conductor to which the current passes is called the *negative electrode.* A common use of the electric arc in the industries is in electric arc welding.

Electric Brakes. See Brakes, Electric.

Electric Currents. Electric currents have been classified by the Standards Committee of the American Institute of Electrical Engineers as follows: A *direct current* is a unidirectional current; as ordinarily used, the term designates a practically non-pulsating current. A *pulsating current* is a current that pulsates regularly in magnitude; as ordinarily employed, the term refers to a unidirectional current. A *continuous current* is a practically non-pulsating direct current. A *periodic current* is an oscillating current, the values of which recur for equal increments of time. An *alternating current* is a current that alternates regularly in direction; unless distinctly otherwise specified, the term "alternating current" refers to a periodic current with successive waves of the same shape and area. An *oscillating current* is a periodic current the frequency of which is determined by the constants of the circuit or circuits. Alternating current has the advantage over direct current in that simpler generating machines and generally more rugged motors may be used; but the chief advantage is that it is possible to obtain and use very much higher voltages than can easily be obtained or used with direct current. Alternating current is, therefore, used whenever distant transmission of electric power is necessary.

Electric Fixture Thread. The special straight electric fixture thread consists of a straight thread of the same pitches as the American standard pipe thread, and having the regular American or U. S. standard form; it is used for caps, etc. The male thread is smaller, and the female thread larger than those of the special

straight-fixture pipe threads. The male thread assembles with a standard taper female thread, while the female thread assembles with a standard taper male thread. This thread is used when it is desired to have the joint "make up" on a shoulder. The gages used are straight-threaded limit gages.

Electric Furnaces. Electric furnaces may be divided into three general classes, according to the method by which the heat is generated: 1. Arc furnaces. 2. Induction furnaces. 3. Resistance furnaces. With regard to the purpose of the furnaces, they may be divided into two large groups, melting furnaces, and heating furnaces. *Arc furnaces* produce heat by means of an electric arc between two electrodes, usually of carbon. The arc furnace may be considered as a resistance furnace in which the resistor is a gas. The resistance of gas at atmospheric pressure is greater than that of any solid resistor having the same dimensions as the arc, and, therefore, the amount of heat that can be produced in a given space is greater in an arc furnace than in any other type of furnace. Arc furnaces are used mainly for melting iron or steel. One type of *induction furnace* may be defined as a static transformer having a low tension "winding" formed by the material to be heated. Induction furnaces are, therefore, exclusively melting furnaces. Another type utilizes high frequency current which heats the material by means of eddy-currents.

Resistance furnaces may be divided into two types, those in which the current is conducted by the materials to be heated with or without electrolysis, and those in which the current is conducted by a special resistor. The charge or the resistor is connected directly to the source of the current supply. The heat developed in both induction and resistance furnaces is generated by the passage of a current through the resistance offered by the charge in the furnace or by the special resistor. Resistance furnaces are mainly used as heating furnaces, but are also employed for melting metals and alloys having a comparatively low melting point.

A special type of furnace which, perhaps, is the most useful of all for melting materials having a low fusing point is one which embodies the principles of both the arc and the resistance furnace, or the induction and resistance furnace. In this type of furnace, the current is started by means of an arc or by means of induction, and, when once a conductor has been established by the melting charge, the heat is maintained as in a resistance furnace.

Electricity. Electricity itself cannot be defined except in a very general way. It may be said to be a form of energy, the same as light and heat. However, electrical engineering deals with what can be *done* with electricity and not with what it is.

In fact, what electricity *is* does not concern the electrical engineer any more than what gravity is concerns the mechanical engineer. Strictly speaking, the exact nature of electricity is not *definitely* known at the present time but the effects due to it and the laws that these effects follow have been very thoroughly investigated and determined. Thus it may be said that electricity is a physical agent pervading the atomic structure of matter and characterized by being separable, by the expenditure of energy, into two components designated as positive and negative electricity, in which state the electricity possesses recoverable energy. The quantity of electricity on (or in) a body is the excess of one kind of electricity (positive or negative) over the other kind (positive or negative).

Electricity in the form of a charge or in the form of a current may be produced either by means of batteries—devices by which chemical energy is transformed into electrical energy—or by means of electric (electromagnetic) generators—rotating machines with conductors for electricity which move with relation to magnets in such a manner that an electric current is produced. Electricity may also be produced by so-called "thermo-couples," that is, by two dissimilar metals placed in proximity to each other and subjected to temperature differences, and by "static machines," in which the electricity is produced by the rubbing of two substances against each other. These two latter methods are of comparatively small commercial importance.

Electric Light Invention. Sir Humphrey Davey discovered in 1809 that the separation of the charcoal terminals of a powerful battery caused the formation of a brilliant electric arc, producing light that exceeded in intensity all the other known forms of light. This discovery led to the development of methods of feeding one carbon terminal toward another in order to maintain an arc, but for many years such arc lights were confined to the laboratory, since the current could only be obtained at that time from batteries. Very efficient electric lamps, however, used in conjunction with batteries, were devised by Foucault, Duboscq, Deleuil, and others, as early as 1853. The real development, however, of the electric light began with the invention of the dynamo. Among those who made notable contributions to arc light development should be mentioned Brush, Weston, Thomson, and Houston.

Although Thomas A. Edison is credited with the invention of the incandescent light by decision of the courts, as well as popular opinion, the first incandescent light is said to have been devised in 1840 by William R. Grove, inventor of the Grove battery. In 1845 an incandescent lamp was patented in England by August King, who acted as an agent for a Mr. Starr, an American inventor. This lamp was known as the Starr-King lamp. The

Jablochkov electric light was first introduced in 1876 to light the streets of Paris. William E. Sawyer applied in 1877 for a United States patent for an electric engineering and lighting system. The form of incandescent electric lamp which resembles in its main features the modern type, was patented by Edison in 1880. This lamp had a thin filament of carbon which was sealed in a vacuum so that it would not burn away but remain incandescent. The small carbon filament and its high resistance permitted proper distribution of current to a number of lamps without special regulation. Moreover, the cost of making lamps was low enough to permit discarding them when the filament was finally destroyed as the result of use. The claims of Mr. Edison were contested by William E. Sawyer and his partner Albon Man, which at first resulted in the grant of a patent to Sawyer and Man in 1885. This was followed, however, by patent litigation in the courts which terminated in 1892 in a decision by the United States Court of Appeals awarding the incandescent lamp to Edison.

Electric Railway Origin. The first electric railway was constructed in Berlin in 1879 by Dr. Werner Siemens. The first electric railway in the United States was constructed in 1885 and extended from Baltimore to Hampden, a distance of two miles.

Electric Riveter. See Riveter, Electric Type.

Electric Shock. An accidental electric shock usually does not kill at once, and may only stun the victim and stop his breathing temporarily. The victim of an electric shock can be restored only by prompt and continued use of artificial respiration. Break the circuit immediately. With a single quick motion separate the victim from the live conductor. In doing so, the person coming to the rescue must avoid receiving a shock himself by using a dry coat, a dry rope, a dry stick or board, or any other dry nonconductor, to move the victim or the wire so as to break the electrical contact. If the body of the victim must be touched by the hands, cover them with rubber gloves, a mackintosh, a rubber sheet, or thick, dry cloth. Also stand whenever possible on a dry board or some other dry insulating surface, and, if possible, use only one hand. If the victim is conducting the current to the ground and he is convulsively clutching the live conductor, it is easier to shut off the current by lifting him from the ground than by trying to break his grasp. Open the nearest switch, if that is the quickest way of breaking the circuit; if necessary, cut the live wire by using a hatchet or an axe with a dry wooden handle or properly insulated pliers. As soon as the patient is clear of the live conductor, begin artificial respiration at once. *Every moment of delay is dangerous.* Continual artificial respiration is

necessary without interruption until breathing is restored; even after natural breathing begins, carefully watch that it continues. If it stops, start artificial respiration again. During the period of operation, keep the victim warm by applying proper covering and by laying bottles or rubber bags filled with warm (not hot) water beside his body. Do not give the patient any liquids whatever in the mouth until he is fully conscious.

Electric Soldering. The general method of electric soldering, as distinguished from soldering with an electric iron, consists of holding the pieces to be joined by clamping jaws with the ends of the work in firm contact; a heavy current of electricity, regulated to heat the joint sufficiently to melt the solder, is next passed through the work. The solder, in the form of tape or wire, is then applied to the joint. It flows in and around all parts heated to the proper temperature, as when using a gas flame, but the "life" or temper is retained in pieces that have been electrically soldered, instead of their being left in an annealed condition as when heated with a flame. Practically all the metals, such as brass, copper, steel, German silver, gold, and silver can be soldered successfully by means of the electric soldering process; this method is the most economical for a continuous run of work. The current used for electrical soldering should be a single-phase alternating current of any frequency between 40 and 60. A higher frequency could be used, but it is not good practice.

This method of joining metal pieces together resembles resistance welding in that an electric current is passed through the work to provide heat at the joint. It differs from it, as all soldering differs from welding, in that none of the metal to be joined is melted.

Electric Steel. Electric steel is so called because it is made in some type of electric furnace. The charge of raw material may be melted in the electric furnace, or the latter may be used for refining molten metal which has been partly refined in the open-hearth furnace. In some cases, the Bessemer converter is also used. The smaller electric furnaces melt cold charges, but some of the larger installations receive the metal in a molten condition. The electric furnace produces high-grade steels and it may be used for making special alloy steels, tool steel, steel castings, and for certain other metallurgical processes. Steel may be produced in the electric furnace that is chemically purer than steel made by any other process.

Electric Welding. In electric welding processes, the parts to be welded together are heated to a welding temperature by means of an electric current. There are two main systems of electric welding: (1) Electric resistance welding; (2) electric arc welding.

Thomson or Resistance Process: The Thomson or resistance process consists in forcing through the parts to be welded such a large volume of current that the resistance of the work is sufficient to cause fusion and welding of the metals. The parts to be welded are held between two clamping members of the welding machine, which form terminals for an electric current of low voltage and high amperage. When these clamps are forced together, the work completes the circuit, and current is transmitted directly through it from one electrode to the other. With this method of welding, the interior of the metal is raised to a welding temperature before the surface reaches that heat, and the heat generation is so rapid that the loss is negligible. Resistance welding makes possible the uniting of forgings and stampings into integral, strong, light-weight parts at a speed unequalled by any other process. A motor car in which practically no castings are used, except in the power plant, can thus be produced.

Resistance Welding Methods: The following terms used in designating resistance welding methods, have been approved as an American Standard by the American Standards Association.

Butt Welding: A resistance welding process wherein a butt joint is employed.

Flash Welding: A resistance butt-welding process wherein the welding heat is developed by the passage of current in the form of an arc across a short gap between the surfaces to be welded, these surfaces being kept slightly separated until they have flashed off to parallelism and have reached the desired temperature. The electrical circuit is then opened and the upsetting movement takes place. The operation of the machine may be manual, semi-automatic, or fully automatic. The name "flash" arises from the fact that during the heating period oxidizing metal is thrown off in a shower of sparks.

Percussive Welding: A resistance welding process wherein electric energy is suddenly discharged across the contact area or areas to be welded and a hammer blow is applied simultaneously with or immediately following the electrical discharge.

Pressure Welding: A process of welding metals in either the highly plastic or fluid state by the aid of mechanical pressure. This process includes the resistance welding form of electric welding and the pressure type of thermit welding.

Resistance Welding: A pressure welding process wherein the welding heat is obtained by passing an electric current between the contact areas to be welded.

Seam Welding: A resistance welding process wherein the weld is made lineally between two contact rollers or a contact roller and a contact bar.

Spot Welding: A resistance welding process wherein the weld

is made in one or more spots by the localization of the electric current between the contact points.

Application of Different Welding Methods: The extent to which different welding methods are used varies in different industries. The types of resistance welding most generally used in the automotive industry are spot-welding, flash butt-welding, upsetting, seam welding, and projection welding. To illustrate the relative use of different methods, one type of car has 3240 resistance welds in the body and chassis, of which 44 are flash butt-welds, 2 are seam welds, and 3194 are spot-welds. In addition, there are a number of welds in the parts made by part manufacturers and by makers of accessories used on this car.

Arc Welding Process: When welding by the arc process one wire of an electric circuit is connected with the part to be welded and the other is attached to an electrode, so that the current passes across a short air gap between the work and the electrode, thus generating intense heat, the air being a poor conductor and offering a high resistance to the electricity. The heat of the arc is the hottest flame obtainable, the temperature varying between 3500 and 4000 degrees Centigrade (6332-7232 F.) according to estimates. By placing the electrode in contact with the metal and instantly withdrawing it a short distance, the arc is established. As the result of the heat thus produced, the metal may be entirely melted away or fused to another piece of metal, as desired. The electrode is the negative terminal and the metal to be welded is the positive terminal. Electric arc welding processes differ both in regard to the type of electrodes used and the kind of electric current.

Arc Welding Terms: Arc Welding—A fusion welding process wherein the welding heat is obtained from an electric arc formed either between the base metal and an electrode or between two electrodes with or without the use of gases.

Arc Welding Electrode: Filler metal in wire or rod form, or a carbon (or other suitable material) rod, used as one (or both) of the terminals in an electric circuit in order to produce a welding arc.

Bare Electrode: A metal electrode which is not fluxed or covered.

Base (Parent) Metal: The material that is welded (or cut).

Carbon Arc Cutting: A process of severing metals by melting with the heat of a carbon arc.

Carbon Arc Welding: An arc welding process wherein a hard carbon or graphite electrode is used, and filler metal, if required, is supplied by a welding rod.

Coated Electrode: A fluxed electrode having the flux applied externally by dipping, spraying, painting, or similar methods.

Composite Electrode: A fluxed electrode having one or more filler materials combined mechanically with the flux or covering.

Covered Electrode: A metal electrode having an external wrapping or braiding of paper, asbestos, or other material. A flux may be included with the covering.

Filler Metal: The material that is added to the base metal to produce the weld in some forms of the fusion welding process. (See "Welding Rod" and "Arc Welding Electrode.")

Flux: Material used in welding to prevent the formation of oxides, nitrides, or other undesirable inclusions in the weld and to eliminate those that have formed. In metal arc welding, it is also employed to aid in the retention of the various elements of the electrode and to retard the rate of cooling of the weld metal.

Fluxed Electrode: A metal electrode provided with a flux.

Flux Encased Electrode: A fluxed electrode having the flux between a metal core and a sheath.

Shielded Carbon Arc Welding: A carbon arc welding process wherein the molten filler and weld metals are effectively protected from the air by supplemental means.

Shielded Metal Arc Welding: A metal arc-welding process wherein the molten filler and weld metals are effectively protected from the air by supplemental means.

Electrochemical Cleaning. Alkaline substances, such as sodium carbonate, potassium carbonate, potassium hydroxide, and sodium hydroxide in solution in varying degrees of concentration, and with small portions of potassium cyanide, develop sufficient hydrogen, with a current of from 4 to 8 volts, with the bath at nearly boiling temperature, to entirely remove all organic substances from the surface of metal, leaving it chemically clean. The action of an electro-cleanser is similar to the action of an electroplating bath. The only difference, as far as the development of gases is concerned, is that no metal being in solution and the anode being insoluble, no metal is deposited; but with a strong current a copious supply of oxyhydrogen gas is developed and attacks the organic matter upon the surfaces of articles to be cleaned, practically lifting off this matter and, by rapid evolution of the gases, carrying it to the surface. The small quantity of potassium cyanide contained in solution absorbs the slight oxidation that might be upon the surface, and by the combined action produces a surface clean enough, after washing in clear water, for any deposits.

The electrochemical cleaning solution should consist (for ordinary purposes) of from 3 to 4 ounces of caustic potash to each gallon of water, and to every 100 gallons of solution, 8 ounces of cyanide of potassium. This can be varied according to condi-

tions. It is advisable to add at least ¼ pound of cyanide each week. Where the articles, such as iron or steel, contain much oil or grease upon the surface, the density of the solution can be increased. For articles of brass, copper, or bronze that have been polished, use a solution of carbonate of soda in the proportion of 2 ounces of soda and ½ ounce of caustic potash to each gallon of water, with the addition of 4 ounces of cyanide to every 100 gallons of solution.

Electrochemical Equivalent. The factor 0.001118 is called the *electrochemical equivalent* of silver; the electrochemical equivalent of other metals will be found in standard chemical and electrical handbooks. There is a simple relation between the electrochemical equivalent of various metals and their atomic weights and valences, which is as follows:

$$\text{Electrochemical equivalent} = \frac{\text{atomic weight}}{\text{valence} \times 96{,}494}.$$

The atomic weight divided by the valence is known as the *chemical equivalent* and the factor 96,494 is known as the *faraday*. The weight, in grams, of a substance carried to an electrode by electrolytic action always equals the electrochemical equivalent of that substance multiplied by the number of coulombs passed through the cell.

Electrochroma. Electrochroma is a plating process for obtaining various colors on metals and alloys by electrolytic action. It is possible to produce various shades of green, blue, red, violet, yellow, or black by immersion of from one-half to two minutes in the electrolyte. The work is made the cathode.

Electrode. The poles or terminals of an electric battery are known as *electrodes*. The pole or terminal which is at the higher potential is called the *positive pole* or *terminal*, while the other pole is the *negative pole* or *terminal*. The positive pole is known as the *cathode* and is the negative electrode, while the negative pole or *anode* is the positive electrode. In a copper-zinc battery, for example, the copper is the positive pole, but the negative electrode or plate.

The elements of an arc lamp or furnace between which an electric arc is struck are termed electrodes.

The positive and negative elements in an electroplating bath are also so designated.

Electro-Deposition on Worn Parts. A simple process, developed at the Westinghouse Research Laboratory, for building up worn parts by the electro-deposition of iron, has been used for shafts, pins, bolts, gear centers and similar parts, and with very little modification can be employed to build up the worn

surfaces inside automobile engine cylinders. Commercial salts are used and a current of sufficient density is employed to permit all ordinary repair work to be removed from the plating bath at the end of two or three hours. The cost of building up and machining is kept low enough so that it will pay to reclaim a piece with this process rather than use a new one.

Cleaning: After thorough cleaning by any conventional means, it is essential, if adherent deposits are to be obtained, to give an anodic treatment in sulphuric acid, using sufficiently high current density to secure passivity. Westinghouse Research Laboratory used 30 per cent H_2CO_4 for about three minutes, at a current density of 3 to 5 amperes per square inch.

The Plating Bath: A plating bath made up in the following proportions has proved best: 2.5 pounds of commercial ferrous ammonium sulphate per gallon of city water plus a small amount of ferrous carbonate (freshly precipitated and kept under water in order to keep the solution practically neutral) plus a small amount of powdered charcoal, which helps to prevent pitting.

The Process: All small pieces are plated in earthenware crocks, and large pieces in lead-lined wooden tanks or stoneware tanks. Waterproof cement tanks can also be used. All contact of the solution with wood should be avoided as this always results in hard, brittle, specular deposits instead of the silvery, ductile ones obtained under proper conditions. The anodes are made of "Armco" iron, and are cylindrical in shape. Micarta disks with a hole cut in the center are fitted in each end of the anodes. The pieces to be plated are made the cathode and held stationary so that they extend into the plating solution through the holes in the micarta disks. The anodes are attached to a device which moves them up and down, thus keeping the plating solution stirred and the ferrous carbonate and charcoal in suspension. The temperature is held at approximately 60 degrees C., a few degrees variation either way not doing any harm. A current density of 0.43 ampere per square inch is used. This deposits metal at a rate that increases the diameter 0.006 inch per hour. This method of procedure applies only to pieces such as shafts, bolts, pins, etc.

Plating Inner Surfaces: For pieces such as gear centers, automobile cylinders, etc., where the inside diameter needs to be reduced, the anode is made to go down through the center, and micarta rings are fastened to the anode to obtain the required stirring. The current density could be raised considerably, but as the density specified adds the deposited material at the rate of 0.003 inch on a side or increases the diameter at the rate of 0.006 inch per hour, it is evident that the ordinary repair job requiring an increase in diameter of approximately 0.010 inch

to 0.020 inch can be quickly completed. It is impossible to build up a piece accurately to size, and so it is necessary to build the work up a few thousandths over-size and then turn or grind it to the finish size. This method of recovery can be used with steel or cast iron, and the deposited material can be case-hardened when necessary.

Electrodes, Welding. See under Electric Welding; also Elkonite Electrodes.

Electrodynamic Ammeter. See Ammeter.

Electrodynamic Wattmeter. See Wattmeter.

Electrodynamometer. The electrodynamometer is used in electrical laboratories for the measuring of electric current and power, especially in alternating-current practice. The instrument depends upon the action of one circuit carrying current upon another circuit carrying the same current. The working parts of the instrument consist simply of two coils, one fixed and the other movable, together with the required indicating means. Commercial instruments of this type for measuring currents are suitable for measurements as small as 0.02 ampere. When properly calibrated and used, the readings of a Siemens electrodynamometer may be relied upon to be accurate within 0.1 per cent, for a full-scale deflection. For smaller deflections, the accuracy is not quite so great.

Electro-Etching. Etching may be done by the use of electricity. When the wires leading from the poles of an electric battery are placed in a solution of copper sulphate, and a copper plate is attached to the positive wire, the object to be plated being attached to the negative, an electroplating outfit is formed. The deposition of a metal will not take place on any substance but a metallic one, and it is this fact which makes it possible to employ electricity in etching. When the battery is in action, the copper is taken from the anode, or article attached to the positive wire, and deposited on the cathode or article attached to the negative wire. First let it be assumed that a piece of sheet copper is used as a cathode. In the ordinary course of procedure, the copper from the anode, when properly regulated, will be removed and deposited in a fairly even surface on the cathode. Now suppose that a design is painted on the anode like the letter A with wax, varnish, or any substance that will not be affected by the solution. When the current is flowing, the copper will be removed only from the exposed surface of the anode; the protected surface will not be affected. In consequence, it will be found that after a time the design will stand out in relief. This illustrates the principle, but the method may be varied; for instance, the

background may be coated instead of the design, in which case the figure will be etched and the ground will stand out. Also, the operation may be performed on the cathode instead of on the anode, in which case the exposed parts are built up. The variations possible in using this process may be shown by the following example: Expose the letter A on an anode of copper or gold. The result will be that the letter will appear in relief. It should then be carefully rinsed in clean water without disturbing the ground. Suppose, for instance, that gold is used and it is exposed on the cathode in a silver bath, the silver being deposited in place of the gold that has been removed. Removing the piece from the bath and cleaning, the letter A is found designed in silver on a background of gold. This method is, of course, applicable to any combination of metals.

Electrolimit Gages. The electrolimit gage combines mechanical gaging with electrical magnification to obtain external and internal measurements. This gage uses a simple balanced bridge circuit, arranged so that any mechanical movement of the gaging points unbalances the magnetic field of the coils, the reading being shown on the micro-ammeter.

The electrolimit gage may be used either in the machine shop or in the inspection department. The degree of magnification is easily adjusted, magnifications of 20,000 to 1 being used where such accuracy is essential, as in the case of checking precision gage-blocks within a few millionths of an inch. The indicating instrument or micro-ammeter can be located at any convenient position.

The automotive industry has taken full advantage of new gaging equipment to facilitate manufacture and at the same time improve the quality of its product. With electrical gages properly designed for each operation, pistons and cylinder bores, as well as wrist-pins and other parts, are accurately graded for selective assembly. Better fits at lower costs, producing quieter and longer-lived engines, have resulted from the use of these modern gages.

Use of Electrolimit Gages in Rolling Sheet Metal: The extensive use of tin plate, strip, and sheet steel has called for increased accuracy and greater efficiency in rolling mill operation. These conditions are similar when materials other than steel are rolled in strip and sheet form. Three types of gages have been responsible for reducing the operating cost of producing strip steel by permitting higher speeds on the mills, with increased accuracy, greater efficiency in mill operation, and increased efficiency in inspection through the continuous classification of the sheared sheets.

The continuous electrolimit gage employs a combination of

mechanical gaging contact and electrical magnification. The gaging rolls control the electrical circuit in such a manner that errors in the material being checked are revealed in a greatly magnified and visible form on a micro-ammeter, which can be located at any desired point remote from the gaging unit. Electrolimit gages as applied to cold reduction mills permit accurate gaging of strip at speeds up to 1500 feet per minute. Some strip tin mills are holding their gage tolerance at ± 0.00025 inch at such speeds.

Sheet Classification: Another application of the continuous electrolimit gage is in the classification of sheets. In this operation, the gaging is done while the material is in the strip form, the sorting of the sheets being accomplished after the strip has been cut to the required lengths on the flying shear. The time relation between the gaging unit and the sorting mechanism can be accurately controlled, thus the gaging and sorting of sheets becomes a dependable operation, and the "off gage" sheets are positively separated from the approved sheets.

Strain Gage: Still another use of the electric gage is in the application of the strain gage for measuring the pressures exerted on rolling mills. Instruments capable of recording, as well as indicating, the loads on the mill have proved their practical value in the rolling of steel, paper, rubber, copper, and on other types of equipment, where it is desirable or necessary to know the exact pressures being exerted. In common with most mechanisms, rolling mills are designed to give maximum efficiency at a predetermined rolling pressure, and the strain gage permits reaching the efficient rolling pressure, as well as reducing the hazard of equipment failure caused by unintentional overloading. Briefly, the strain gage measures the stretch in the housing when pressure is applied, and converts this stretch of thousandths of an inch into pounds pressure. The result can be read on an indicating instrument remote from the mill.

Electrolon. The trade name "Electrolon" is used by the Abrasive Company for Silicon-carbide products. See Silicon Carbide.

Electrolysis. The corrosion of metal in the earth or in structures, due to the action of stray or leakage currents from conductors carrying electric energy, is caused by electrolysis. Electrolytic corrosion of underground structures occurs, in general, wherever current flows from the metallic structure into the earth. Many methods have been proposed or tried for reducing or eliminating damage to pipe systems and other sub-surface metallic structures due to stray earth currents from street railways. Some of these have been used widely with more or less benefit in many instances, and with apparent failure in others. There are various means by which electrolysis may be mitigated, which are applicable to the negative return of a railway system; these

include the use of an alternating-current system; use of double-trolley systems; use of negative trolley; periodic reversal of trolley polarity; methods of construction and maintenance of way; grounding of tracks and negative bus; uninsulated negative feeders; insulated negative feeders without boosters; insulated negative feeders with boosters; use of three-wire systems; and location of power houses and sub-stations.

Electrolyte. An electrolyte may be generally defined as a conducting medium in which the flow of electric current is accompanied by the movement of matter. An ionized solution which is used to conduct an electric current is an electrolyte. The liquids in a primary cell, a storage battery, an electroplating bath, are all electrolytes. See also Ionization.

Electrolytic Copper. This is copper that has been refined by the electrolytic method. Such copper ordinarily contains 99.9 per cent of pure copper and has an electric conductivity of about 97 (silver = 100). The electrolytic method for refining copper consists simply in electrolytic deposition of copper on the cathode while the impurities fall to the bottom of the tank with the slime. On account of its purity, electrolytically deposited copper demands a higher price than other copper, except Lake Superior native copper.

Electrolytic Refining. The process of electrolytic refining consists in electrolyzing anodes of the impure metal in a solution of some suitable salt of the metal, starting with cathodes of the pure metal. The metal to be refined dissolves at the anode, passes through the solution, and is deposited on the cathode in a higher degree of purity. The impurities are separated from the principal metal both at the anode and at the cathode. The most important metal refined by the electrolytic process is copper. Copper is refined to recover the valuable impurities, such as gold, silver, and platinum, and to increase the electric conductivity of the copper, for use in electric machines and the transmission of power. Very small amounts of impurities considerably reduce the conductivity. A solution of sulphuric acid and copper sulphate is used in copper refining as the electrolyte. To this mixture, from 0.01 to 0.02 per cent of glue is added so as to cause the copper to be deposited more evenly.

Electromagnetic Hardness Testing. With an electromagnetic hardness testing instrument it is possible to determine the hardness of ferromagnetic metals, such as iron and steel, through the magnetic capacity of the metal. The action of the instrument depends upon the following laws, which hold with every variety of iron and steel: The magnetic capacity is directly proportional to the softness of molecular freedom. The resistance to a feeble

external magnetic force is directly as the hardness or molecular rigidity. It has been shown, by direct experiments, that the molecules of iron are magnets, and that the cohesive force of each molecule is governed by the magnetic force. The cohesive force of the molecules determines the strength and properties of the metals; consequently, when the respective governing forces are measured, the true value of the quality of the metal will be determined.

Electromagnets. A conductor carrying an electric current creates a magnetic field around it. If the wire or conductor carrying the current is wound in the form of a loop, the magnetic field intensity inside of the loop will be much greater than that outside, because the magnetizing force of the entire loop is concentrated within that space. If several turns are made, forming a coil, each turn will add its share of magnetizing force, and produce a field of strong intensity inside of the coil. Now, if an iron bar is placed in the center of this coil, it will be magnetized, the total flux being greatly increased. The combination of the coil and iron core is called an *electromagnet*. The winding need not be distributed over the whole core, but may be concentrated in a coil in any convenient manner; and either a large electric current and a few turns of wire or a small current and many turns of wire may be used to produce the same amount of magnetizing force. An electromagnet has poles the same as a permanent magnet. The poles will depend upon the direction of the winding and the passage of the current through the conductor.

The field poles of electric motors and dynamos are electromagnets. Electromagnets are used also where there is a relatively small movement of the armature and a small air gap in relay mechanisms, such as for operating telephones, electric horns, bells, controller mechanism, automatic switches, etc. They are also used extensively on switchboards of both direct and alternating circuits, and are seen in operation in almost every manufacturing plant. Direct-current magnets have soft iron cores, and their armatures do not require any pole-shading devices like the alternating-current magnets.

Electromagnets for Alternating Current. Some electromagnets are designed to utilize alternating current. The pole shader in an alternating-current magnet is a short-circuiting ring or coil embedded in the pole face to retard the time-phase relation of the magnetic flux within the ring so that there is, at every instant, enough magnetism to hold the magnet closed. Magnets having two and three separate windings are used on two- and three-phase circuits to provide a constant pull at any moment of operation.

Electrometallurgy. Metallurgy may be defined as the art of extracting metals from ores, and refining them to the purity required for commercial purposes. Metallurgical operations are, in general, chemical operations, because ores, with few exceptions, contain the metals as chemical compounds, and, therefore, it is usually necessary to decompose the compounds by chemical reagents. *Electrometallurgy* is the art of utilizing the electric current in obtaining metals from their ores or for refining them for industrial purposes. The methods used in electrometallurgy may be divided into electrolytic and electrothermal. Each of these methods embrace several processes.

Electrometer. An electrometer is an electrical instrument for measuring differences of potentials. This instrument operates by means of electrostatic forces giving the measurements either in arbitrary or in absolute units. There are three classes of electrometers: 1. Repulsion electrometers. 2. Attracted-disk electrometers. 3. Symmetrical electrometers.

Commercial types, known as electrostatic voltmeters are used for high-voltage measurements.

Under certain conditions electrometers may be used to measure very small amounts of power and are then designated as electrostatic wattmeters. See also Electroscope.

Electromotive Force. The work done in moving a charge of electricity along any path or circuit in an electric field is defined as the *electromotive force* acting along that path.

A battery, a generator, a thermocouple, or any other device which acts as a source of electrical energy, actually provides a difference in level of electrical energy (potential) between two or more terminals. If a suitable path (conductor or circuit) is provided between the terminals of such a device, then energy will flow from the "higher" to the "lower" level (potential).

The electromotive force of a device then manifests itself as the means for causing, or tending to cause, the flow of electricity (current) from one terminal to another.

When the source of electromotive force is a battery, the electric energy is derived from the change of free energy accompanying the chemical reaction that occurs in the battery. When the electromotive force is provided by a thermocouple, the electric energy is derived from the heat that is absorbed at the hot junction (Peltier effect), and to some extent from heat absorbed at those parts of the leads where there is a temperature gradient (Thomson effect). When the electromotive force is provided by a changing magnetic flux through the circuit, as in a dynamo generator or in the output circuit of a transformer, the energy is derived from the energy of the magnetic field whose changing relation to the circuit gives rise to the electromotive force.

A potential difference may or may not represent an electromotive force. If it is the result of the passage of current through a resistance, for example, it merely represents a drop in potential, and not electromotive force. Wherever there is an electromotive force, however, there is always a potential difference.

In order to originally create a potential difference between two terminals of a device acting as a source of electromotive force, work had to be done inside the device in the conversion of mechanical, thermal, or chemical energy into electrical energy having different potential levels. The electromotive force between the two terminals is a measure of this work. If it were considered that the difference in energy level was actually created not by mechanical, thermal, or chemical energy being converted inside the device, but by the movement of charges of electricity through an external circuit from one terminal to the other, the work done per unit charge would be equivalent to the electromotive force established between the two terminals. Or, to put it in different terms, the electromotive force between these two terminals represents the amount of energy available between them per unit quantity of electricity or charge.

Electromotive force is measured in volts; and from the standpoint of "work done" or "energy available," one volt equals one joule of energy per coulomb quantity of electricity. If a source of electromotive force were connected to an external circuit of homogeneous resistance at constant temperature and a continuous current flowed through this circuit, then the electromotive force in volts is equal to the current in amperes times the resistance in ohms.

Electronic Tubes. An electronic tube is an electrical device consisting of an enclosure, usually of glass or metal, from within which the contained atmosphere has been evacuated to a high degree (and which may or may not be replaced by some kind of gas) and a number of metal elements called electrodes which are supported at various distances from each other within the enclosure. Electrical connection with these electrodes is usually made through a sealed base or cap to terminals which may take the form of prongs. These permit quick insertion in and removal from a holding socket, so that damaged or worn out tubes may be replaced easily.

Electronic tubes are used for a wide variety of purposes and their design is highly specialized and adapted to their intended function.

When used as *rectifying tubes* (for conversion of alternating current to direct current), they usually have two electrodes (cathode and anode) between which the passage of current is unidirectional. A third element, or grid, is sometimes incorporated

to control the starting of the unidirectional current flow. Three-element types may also be used in inverter circuits for the conversion of direct current to alternating current.

When used in radio or communication equipment as *detectors*, *amplifiers*, *modulators*, and *oscillators*, there are one or more additional elements present which may be placed between the anode and cathode to control the current flow. Only an exceedingly small variation in the potential of the controlling element or *grid*, as it is sometimes called, is needed to effect relatively large changes in the current flow between anode and cathode. These types of tubes may be used as very sensitive relays.

X-ray tubes are quite different in design as compared with rectifying or communication types of electronic tubes. In X-ray tubes the anode and cathode are separated by a much greater interval and a third element in the form of a target is introduced and this is electrically connected to the anode. The stream of electrons which constitutes the current flow between cathode and anode strikes or "bombards" the target causing the emission of rays of exceedingly short wave length (shorter than ultra-violet light) and of high penetrating power, i.e. ability to pass into or through substances of considerable density such as metals. The wave length and penetrating power of these rays is a function of the density of the metal in the target and the magnitude of the potential difference between anode and cathode. Notable developments have been made in the design of X-ray tubes operating at exceedingly high voltages and having deep penetrating power.

In *cathode ray tubes* the electronic stream or *cathode ray* is directed and focused into a beam which falls upon a fluorescent screen at the end of the tube. In impinging upon this screen the cathode ray causes a luminous spot of varying intensity to be formed. By means of additional elements which may take the form of plates (for electrostatic control) or coils (for electromagnetic control) this beam may be made to move longitudinally and horizontally across the luminous screen in synchronism with the electrical impulses of the circuit in which the tube is connected. Thus a pattern may be traced in the form of a sine wave or some other wave shape when the tube is used in an electronic oscillograph or a complete picture may be produced by rapid "scanning" as in the case of a television tube.

In *phototubes* a target of light sensitive metal is provided as one element in the evacuated or gas filled enclosure. Usually the tube itself is covered or shielded from light except for a single aperture of glass or quartz. When light passes through this aperture and falls upon the target (cathode), a stream of electrons is emitted from the target and, in passing to the other element of the tube (anode) and around through the external circuit

connecting the two elements, a feeble electric current is, in fact, created. Thus, these tubes may be used wherever the function of converting light impulses into electrical impulses is needed, as in meters for the measurement of light intensities, light relays for the protection of machine operators, regulation of equipment, lighting systems, etc., and as "scanning" tubes for picking up various scenes for transmission by television or wired picture transmission.

Electronic tubes may be divided into two broad classes according to their gaseous content: *High vacuum tubes* are those which have been evacuated to such a degree that their electrical characteristics are essentially unaffected by gaseous ionization. *Gas-filled tubes* are those in which the pressure of the contained gas or vapor is such as to affect substantially the electrical characteristics of the tube.

Electronic Tubes, Industrial Applications. Electronic tubes are being used for a wide variety of functions in industry such as counting, indicating, limiting, actuating, measuring, inspecting, sorting, time control, color matching, regulating, signaling and protection of operators and machines. They are especially adapted to making certain types of measuring devices entirely automatic and to increasing the precision and consistency of such instruments under manual operation. Electronic gages are used for measurement down to 0.00001 inch and inspection gages which automatically measure small parts for length, concentricity and hardness utilize electronic tubes. The phototube is useful in controlling electric motors and motor-driven equipment, heat processing furnaces, lights and the timing of resistance welding operations.

One interesting function is the continuous inspection of sheet steel as it passes through a shearing line. Light beams are directed on the moving sheet in such a way that when minute holes, usually imperceptible to the eye, appear, light passes through them and strikes the phototube causing the control circuit of the shearing machine to be actuated. Textile looms are equipped with phototube controls for stopping the operation when a thread breaks (see illustration). Light targets are suspended from each thread and when a thread breaks, its target drops and interrupts the light beam focussed on a phototube. This provides the controlling means for stopping the loom. Protection of machine operators where parts must be manually inserted and removed is accomplished by establishing a "curtain of light" around the working area of the machine, so that if interrupted by the worker or any object while the machine is in operation, the phototube operates immediately and the machine is stopped. This "curtain of light" is made possible by means of several phototubes

lined up behind a continuous row of lenses. A similar arrangement is used to prevent machines from continuing their operation before a previously processed part is removed, thus protecting both machine and product.

The so-called gas-filled electronic tubes find a wide field of application. They are used for voltage control and regulation, for manual or automatic speed control where stepless, accurate regulation is necessary. For example, tube control is used to correlate the speeds of various sections of rubber process conveyors to maintain a given loop of rubber sheet between conveyor sections. Another application is for varying over wide ranges the

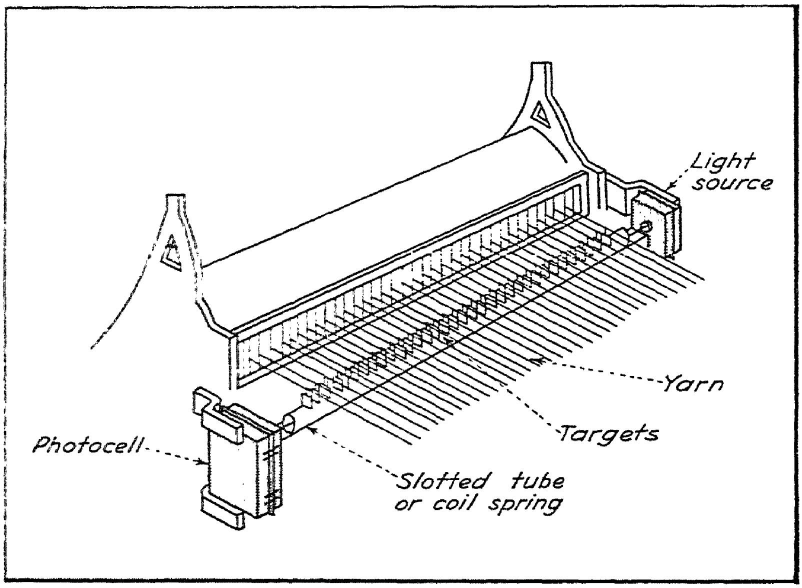


Photo-electric Control of Textile Machine

speed of direct-current motors driving frequency changers which supply power to high-speed textile motors, and for maintaining the speed of motors within narrow limits at any given setting regardless of wide load changes. The use of vapor-discharge control tubes for the control of power flow to resistance welders has revolutionized the method of fabrication of many high-production units such as refrigerators, cans, vacuum tubes, etc. The control of light by the vacuum-tube-reactor dimming method is recognized as most efficient and flexible. X-ray tubes are now being utilized in equipment designed especially for the examination of castings and large machine parts where the detection of hidden flaws is important.

Electronic Tubes, Industrial Types. In the class of high-vacuum tubes for industrial purposes, there may be mentioned the kenotron, the phototube, the pliotron, and the magnetron. In the class of gas-filled tubes for industrial purposes, there is the phanotron, the glow tube, the pool tube or tank, the phototube, the thyratron, the grid glow tube, the grid pool tube or tank, and the ignitron.

The *kenotron* is a high-vacuum thermionic tube in which no means is provided for the control of unidirectional current flow.

The *phototube* is a vacuum tube in which the electronic emission is produced directly by radiation falling upon an electrode. A high-vacuum phototube is one which is evacuated to such a degree that its electrical characteristics are essentially unaffected by gaseous ionization.

The *pliotron* is a high-vacuum thermionic tube with one or more electrodes employed to control unidirectional current flow.

The *magnetron* is a high-vacuum thermionic tube in which a magnetic field is employed to control the unidirectional current flow.

The *phanotron* is a hot-cathode, gas-discharge tube in which no means is provided for controlling the unidirectional current flow.

The *glow tube* is a cold-cathode, gas-discharge tube in which no means is provided for controlling the unidirectional current flow.

The *pool tube* (or tank) is a gas-discharge tube (or tank) with a pool-type cathode (liquid or solid) in which no means is provided for controlling the unidirectional current flow.

The *phototube* of the gas-discharge type is one in which a quantity of gas has been introduced, usually for the purpose of increasing its sensitivity.

The *thyratron* is a hot-cathode, gas-discharge tube in which one or more electrodes are employed to electrostatically control the starting of unidirectional current flow.

The *grid glow tube* is a cold-cathode, gas-discharge tube in which one or more electrodes are employed to control electrostatically the starting of unidirectional current flow.

The *grid pool tube* (or tank) is a gas-discharge tube (or tank) with a pool-type cathode (liquid or solid) and with one or more electrodes provided for controlling electrostatically the starting of unidirectional current flow.

The *ignitron tube* is a gas-discharge tube (or tank) with a pool-type cathode (liquid or solid) in which an ignition electrode is employed to control the starting of unidirectional flow of current in each operative cycle.

Electron Metal. Electron metal, a very light constructional metal, was first placed on the market in 1909 by the Griesheim-Elektron works in Germany. It is an alloy of magnesium, having a specific gravity but two-thirds that of aluminum, with great tensile strength and machinability. The fact that it contained magnesium caused much prejudice against its use at first, most people only knowing that metal in the shape of wire or powder of great combustibility. It is true that electron metal, after melting, is very oxidizable, its blinding white light being characteristic, but, as its melting point is as high as that of aluminum—about 1200 degrees F.—its combustibility need not be considered unless the metal is to be used under exceptional conditions as to temperature. Of this the greatest proof is afforded by its use in internal-combustion engine pistons, where it is constantly exposed to the exploding gases. Its chemical character restricts its sphere of application, being unsuitable for articles which are in constant contact with running water, acids, or acid solutions. When exposed to the atmosphere, a gray coating of rust forms but this coating does not, like iron rust, extend further into the metal, which is, in the case of electron metal, saved from further attack. The application of oil or grease entirely prevents the formation of such a coating.

Electron Theory. According to the "electron theory," matter is composed of *atoms,* which, in turn, are made up of *electrons* in very much the same way that stars and planets form solar systems. The atoms of various materials differ in the number of electrons they contain and in the arrangement of these electrons into systems; but the electrons are, apparently, the same in all matter. The central element of each atom around which the electrons in that atom revolve is called the *nucleus.* In the case of the hydrogen atom, this nucleus is made up of a single particle called the *proton,* and this was at one time considered to be a natural elemental quantity of positive electricity. Recent investigation seems to indicate, however, that the proton is made up of smaller particles which have been given the name of *mesotrons.* The electron, on the other hand, is considered to be a natural elemental quantity of the negative of electricity. The mass of the proton is 1847 times the mass of the electron. The nuclei of more complex atoms are made up of several protons and electrons, with the number of protons being in the excess. Relative to their size, the distance between a nucleus and the electrons revolving about it in an atom might roughly be compared to the distance between the sun and the planets which revolve about it—i.e., the distance between the elemental particles of an atom are enormous in proportion to their size.

Other elementary particles have also been found to exist ac-

cording to recent physical research. These are the *neutron* which is considered to be an uncharged particle of about the same mass as the proton, and the *positron* which is considered to be a particle of positive electricity with a mass about the same as that of the electron. Because of their rare occurrence as isolated entities, however, little is known of their properties.

Electroplating. Electroplating is the art of making electrolytic depositions of one metal on another for the purpose of improving the appearance of the metal covered, or the wearing qualities, or both. In order to deposit one metal on another in a smooth, firmly adhering layer, the surface to be covered must be perfectly clean and the electrodeposition must be carried out under the proper conditions. There are five factors that determine whether or not the metal deposit is of a smooth, firm, adherent character: 1. The kind of dissolved salt from which the metal is deposited. 2. The strength of the solution. 3. The temperature of the solution. 4. The current density on the cathode. 5. The thickness of the deposit. The operation of plating consists of the following: 1. Cleaning and smoothing of the surface to be plated. 2. The electrodeposition of the metal. 3. The final polishing.

Two laws which govern the process of electroplating were established by Faraday. These state (1) the mass of a substance liberated or deposited by an electric current is proportional to the current and to the time it exists, and (2) when the same strength of current is sent through different electrolytes, the masses of the different substances deposited or set free in the same length of time are proportional to their respective chemical equivalents.

The tanks for electrodeposition are usually made of wood lined with lead or of welded steel, with or without a lining, depending upon the type of plating being done. The object to be plated forms the cathode, while the anode supplies the plating metal. The anodes are sometimes fitted with filter bags to collect any sludge resulting from impurities.

The anodes and cathodes are suspended from metal bars running lengthwise of the tanks. The cathodes are suspended between two rows of anodes so that the metal will be deposited evenly on both sides. The cathodes are suspended from the metal rods by means of soft copper wire. Very small objects, such as tacks, pins, and screws may be placed in a metal basket and suspended from the cathode rod, a drum with nonconducting, perforated walls may be used or in the case of large-scale automatic production, a continuous conveyor may be utilized.

The water used to make up the plating solutions should be clear and pure; usually the water supply of modern cities is sufficiently pure for the purpose. The chemicals used should also be of a

fairly high grade of purity. The thickness of the deposit depends upon the current density and the duration of the plating. The value of the current density can be varied only within certain limits that have been found to give good deposits. In plating an uneven surface, more metal deposits on the elevated portions and on the edges than in the depressions; the variation in thickness may be as much as 1 to 10 for different parts of the surface.

Nickel is extensively used in electroplating because of its good wearing qualities, pleasing appearance when polished, the fact that it is not blackened by sulphur compounds, and its very slight tendency to oxidize even in the presence of moisture. It also makes an excellent under-coating for plating with other metals.

Chromium has been utilized widely where a lasting bright and highly corrosion-resistance finish is desired. It is most often plated over a nickel under-coating.

Cadmium is also used to a limited extent for protective purposes.

Copper has been superseded to a considerable degree by other types, although it is frequently used as an under-coat for nickel.

Zinc is used for industrial protective purposes.

Color-plating is also more or less common. In one process, an entire range of colors may be obtained from a single bath, depending upon the length of time that the article remains in the bath. See also Ionization.

Electro-Positive. Of the various methods used to protect iron from corroding or rusting, the application of a zinc surface is one of the most effective. This is due to the fact that zinc is one of the few moderate-priced metals which is electro-positive to iron. To understand the meaning of this statement, it is necessary to know what takes place during the corrosion of a piece of iron or steel that is protected by a coating of some other metal. The corrosive action is started by the setting up of a galvanic electric current, which results in carrying metal to the negative pole of the electrolytic cell. In the case of zinc, which is electro-positive to iron, a galvanic action of this kind causes a slight depletion of the zinc at points where such an action is proceeding, but does not damage the iron. With iron or steel products covered with a coating of some metal which is electro-negative to iron, the result of such a galvanic action would be the reverse; namely, there would be a depletion of the iron beneath the coating of the second metal which covers the work. It is of interest to note that the corrosive action caused by a galvanic current can only take place where there is a flaw in the coating of zinc or other metal with which the iron is covered, that allows moisture to gather. But as it is practically impossible to produce a coating

in which there are not at least a few very small openings, the effect of the galvanic action that takes place at such points becomes a matter of importance.

Electroscope. The electroscope is an instrument used for detecting the presence of an electric charge, or, in other words, differences of electrical potential or electrification. One of the earliest forms of electroscope consisted of a light metallic needle balanced on a pivot the same as a compass needle. An improvement on this type consisted in simple forms of repulsion electroscopes, in which two similar electrified bodies repelled each other. The uses of the electroscope are to ascertain if any body is in a state of electrification and to indicate whether the charge is positive or negative. See also Electrometer.

Electrowinning. Electrowinning is the electrodeposition of metals or compounds from solutions derived from ores or other materials using insoluble anodes.

Electrum. Same as German Silver.

Element. In chemistry, an element is a substance which consists of chemically united atoms of one kind. The substance cannot be changed by chemical action into some other substance or substances, except by the addition of some other element that can combine with the atoms of the original element; hence, iron, lead, sulphur, hydrogen, etc., are elements.

Elesco. An aluminum bronze that does not have an affinity for stainless steel, and hence does not load up with particles of steel that scratch the work when used for press dies. Adapted for drawing and forming dies for stainless steel, but not recommended for blanking or other cutting operations.

Elkonite Electrodes. Copper is ideal as electrode material, insofar as electrical conductivity is concerned, but for many classes of service it is lacking in strength and durability and for certain applications its use is entirely impracticable. The pressures which must be applied for some welding operations are so high that copper electrodes are rapidly compressed and distorted, especially after being annealed by the heat incident to welding; consequently, the contact area is increased, thus decreasing the resistance to current flow and the amount of heat generated. As a result the quality of the weld is impaired, unless provision is made for increasing the amount of current to offset the increase in contact area. In other applications where the electrodes are utilized to accurately locate the parts to be welded, the deformation of the electrodes due to clamping pressures and compression of the metal, results in gradually changing the location of the parts so that the work is done inaccurately.

The difficulties referred to in connection with copper electrodes, have been overcome by the introduction of electrodes composed of tungsten and copper in proportions that are varied to suit the class of service. This electrode material is known as "Elkonite." It is not a true alloy, but rather a mechanical mixture of tungsten and copper. For some purposes there is 50 per cent of tungsten and 50 per cent of copper, whereas for other applications the tungsten content is increased up to 80 per cent.

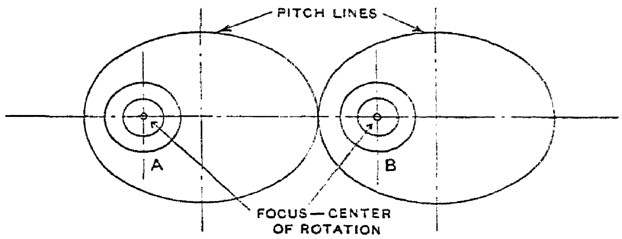
Elkonite electrodes are from about 100 to approximately 500 times more durable than copper electrodes. They are especially recommended for operations requiring either higher compressive strength than copper, or a somewhat higher resistance. The latter, for instance, is a factor in welding satisfactorily certain nonferrous metals such, for example, as aluminum. This type of electrode consists of an Elkonite insert only, the main body being of copper.

Ellipsograph. The ellipsograph is an instrument employed for drawing ellipses on the drafting-board. A number of different designs have been developed, some of which are obtainable as commercial products in the market.

Ellipsoid. An ellipsoid is a solid body of such shape that all the sections passing through its center are ellipses. If the ellipsoid is formed by an ellipse rotating about its major axis, all the sections on planes parallel to the minor axis of the generating ellipse will be circles, and the solid body so formed is known as an *ellipsoid of revolution*, or a *spheroid.*

Elliptical Chucks. Elliptical chucks are used to a limited extent in machine and tool work and much more extensively in woodworking and metal spinning. In die-making, elliptical chucks are useful for turning or boring oval punches and dies. For woodworking, elliptical chucks are used for such operations as the turning of oval frames and in connection with ornamental work. Chucks of this type are also used for metal spinning in order to produce the various elliptical and oval shapes in which sheet metal parts are made.

Operation: A combined rotating and lateral motion is derived from some mechanism in order to generate the elliptical curvature. The rotary motion may be given to the work and the lateral motion to the tool, but the most common arrangement consists of a special form of chuck which is so designed that the combined motion is imparted to the work, the turning or boring tool being held and used in the usual way. These elliptical chucks differ more or less in their construction, but the fundamental operating principle is the same. The chuck is essentially a rotary compound slide, the action of which is regulated by an adjustable



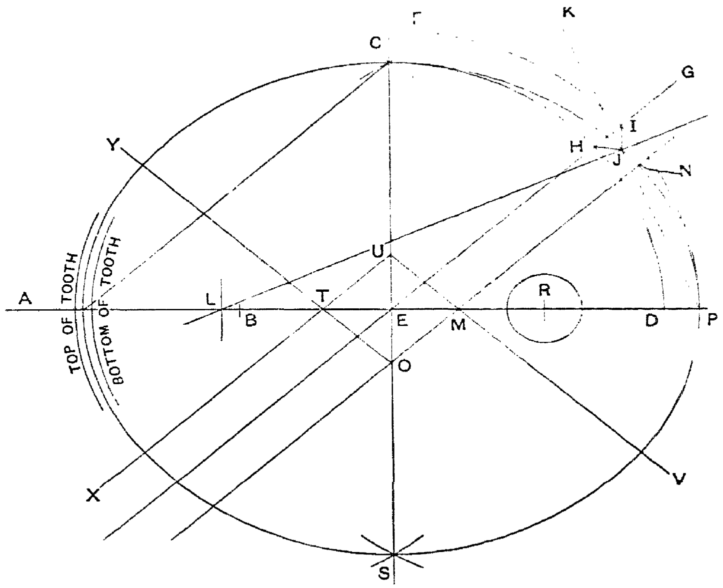


Fig. 1. (Upper Diagram) General Arrangement of Elliptic Gears. (Lower Diagram) Laying out an Ellipse by Means of Circular Arm

eccentric ring for obtaining an ellipse with the required major and minor dimensions.

Elliptic Gears. Gears of this type provide simple means of obtaining a quick-return motion but they present a rather cumbersome manufacturing problem and, as a general rule, it is preferable to obtain quick-return motions by some other type of mechanism. When elliptic gears are used, the two gears that mesh with each other must be equal in size, and each gear must revolve about one of the foci of the ellipse forming the pitch line, as indicated by the upper diagram, in Fig. 1. By the use of elliptic gears so mounted, it is possible to obtain a variable motion of the driven

shaft, because the gear on the driving shaft, while revolving one-half of a revolution, will engage with only a small portion of the circumference of the driven gear, while during the other half of its revolution, the driving gear will engage with a great deal more than one-half of the total number of teeth in the driven gear; hence, the cutting stroke of a machine tool, for example, may be made to have a slow motion, while the return stroke is at a rapid rate. The ellipse has two points, each of which is called a *focus*, located as indicated at *B* and *R*, lower diagram. The sum of the distance between the foci and the elliptic curve is constant at all points and is equal to the longer or major axis *CD* of the ellipse. On account of this peculiarity of the ellipse, two equal ellipses can be made to mesh with each other during a complete revolution about their axes, if one is mounted on a shaft at its focus *A* and the other at its focus *B*, as shown by the upper diagram.

Laying Out Elliptic Gears: The method of laying out elliptic gearing and the cutting of the teeth is an approximate process which may be done in a number of different ways. In the following, a practical case will be explained, indicating the methods that may be followed. The following general principles must be taken into account in laying out the teeth in elliptic gears: The axes must come in line at the time when the teeth that are at a maximum distance from the focus or center of rotation of one gear mesh with the teeth that are at the minimum distance from the center of rotation in the other gear, as in Fig. 1, upper diagram. In order to assure this, the teeth of one gear must be arranged to suit the location of the teeth in the other gear, so that they slip properly into mesh at the point where the axes are in alignment. In addition, it is desirable to have the teeth located in the two gears exactly alike, so as to make it possible to cut them at the same time, while mounted on the same arbor. To obtain this condition, a different arrangement of the teeth is necessary, according to whether the teeth are odd or even in number. If the number of teeth is odd, the major axis of the ellipse should bisect a tooth at one end and a tooth space at the other, as shown in Fig. 2. If the number of teeth is even, one tooth must be tangent to the major axis at the pitch line, as shown in Fig. 3. Little, if any, mathematical treatment is required for the laying-out of elliptic gears that are to be cast from patterns.

Obtaining the Pitch Line: Referring to Fig. 1, lower diagram, the major axis *AP* is equal to the distance between the centers of the shafts on which the gears are to run. The hub of the gear is placed at one of the foci *B* of the ellipse. The positions of the foci *B* and *R* are determined by the ratio of quick return desired; that is, the foci points *B* and *R* should be so placed that the distance *PR* is in the same ratio to *AR* as the given quick-return

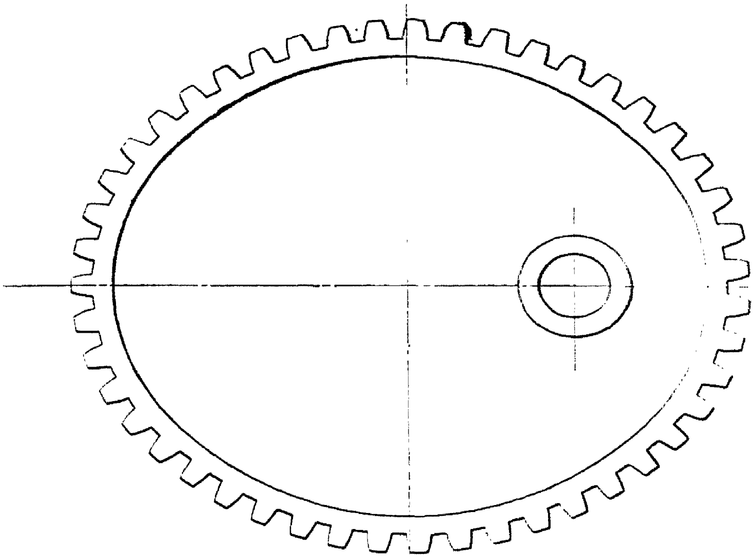


Fig. 2. Relative Position of Teeth and Axes when Number of Teeth is Odd

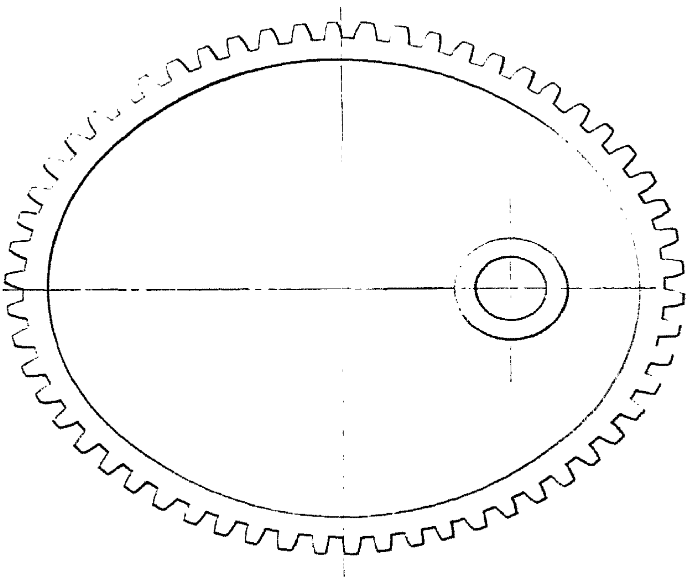


Fig. 3. Relative Position of Teeth and Axes in an Elliptical Gear with Even Number of Teeth

motion desired in the gearing. For example, in a gear, the major axis of which is 8 inches, a given quick-return motion of 1 to 3 is desired; then *PR* would equal 2 inches and *AR* would equal 6 inches, because $2:6 = 1:3$. Having determined the major axis and foci of an elliptical gear, the length of the minor axis may now be found by using one of the foci *B* or *R* as a center, and, with a radius equal to one-half the major axis, cutting the line of the minor axis at *C* and *S*.

When the minor axis has been found, proceed as follows to construct the ellipse: With the point *E*, where the major and minor axes intersect, as a center, and a radius equal to *EC*, draw arc *CD;* then, with *EP* as a radius, draw arc *PF*. Now draw a line *AC* as shown, and through *E* draw a line *EG* parallel to *AC*. From the intersection of the line *EG* with the arcs *CD* and *PF*, as shown at points *H* and *I*, draw lines parallel to the axes of the ellipse which will intersect at point *J*. Draw line *PK* through *J*, and at *J* erect a perpendicular to line *PK*, intersecting the major axis at *L*. Next bisect *LP*, thus obtaining point *M*. Through *M*, draw a line *MN* parallel to *AC*, intersecting the minor axis at *O;* lay off *ET* and *EU* equal to *EM* and *EO*, respectively, and draw *UMV*, *UTX*, and *OTY*. Now, using *M* as a center and a radius equal to *MP*, draw arc *NPV*. Then from center *U*, with a radius equal to *US*, draw arc *VSX*. From center *T*, with a radius equal to *TA*, draw arc *XAY*, and, from center *O*, with a radius equal to *OC*, draw arc *YCN*. If the work has been done carefully, all the arcs will match, giving an approximately true ellipse.

Spacing the Teeth: Having obtained the pitch line of the gear in the manner described, the completion of the pattern by the forming of the teeth must next be considered. The following method has been selected because of its simplicity and the fact that no special jigs or tools are necessary in making the master pattern. The pitch of the tooth must first be decided. In the case just considered, 8 diametral pitch was selected. The distance of the top and bottom of the tooth from the pitch-line is now laid off on the drawing and shown by arcs drawn parallel to the pitch-line from the centers *M*, *O*, *T*, and *U*, Fig. 1. The line of the top and bottom of the tooth being drawn as directed, the teeth may now be spaced off on the pitch circle. The simplest method for doing this is to use the dividers, which should be set at one-fourth the circular pitch of the tooth. This may be obtained by dividing 3.1416 by four times the diametral pitch of the gear. For example, if the diametral pitch is 8, then $\frac{3.1416}{8 \times 4}$ equals one-fourth of the circular pitch. This distance being found, set the dividers to it and follow the outline of the pitch circle very carefully, marking every fourth step.

By using steps of one-fourth the circular pitch as recommended, the pitch-line may be more closely followed and, at the same time, the width of the tooth and space, as well as their center-lines, will be obtained. It is now a simple matter with a radius of suitable length to lay out the teeth which should be made with a simple curve, the same as commonly used on plain cast gears. This curve may be closely approximated by using a radius equal to one-fourth of *OC*.

If it is found after spacing the teeth that their number is even, the teeth must be located with relation to the major axis as shown in Fig. 3, but, if the number of teeth is odd, then the major axis must bisect a space and a tooth as shown in Fig. 2. This is necessary in order that the two gears shall mesh, as already explained. It is evident that when the teeth are spaced by dividers, the spacing will not generally come out exact at the first trial. The spacing must then be increased or decreased slightly until the perimeter of the ellipse is found to be evenly divided. It would be possible to obtain the approximate length of the perimeter by one of the empirical formulas found in handbooks for this purpose, and to find the number of teeth by dividing the circular pitch into the length of the perimeter; but, as the result thus obtained would only be approximate, trial spacing with dividers would still be necessary, and little would be gained by this procedure. Hence, the method outlined is more practical than any in which the mathematical treatment is used.

Forming the Teeth: The number and location of the teeth having been determined, it now becomes necessary to form the tooth. This may be done in two ways. If no other means are convenient, the teeth may be cut directly into the pattern by hand, using an ordinary chisel and following the exact outline of the tooth as laid out in the pattern. This method, while entirely practical, is quite slow and tedious, and, where possible, the following method is recommended. Having found the center-line of the teeth on the pitch circle, project it to the base or root circle of the pattern, marking each point distinctly. Now cut away everything above the root circle and finish the pattern carefully to this line. Next, from a straight piece of clear-grained hard wood, cut a rack on an ordinary gear-cutting machine. This rack should have at least as many teeth of the same size and pitch as are required for the elliptical gear. These teeth when finished should be cut free from the rack and fastened to the elliptical gear pattern blank with wire brads and hot glue, spacing them as shown by the points previously projected to the root circle. After the glue has had time to set and the teeth are securely fastened, wax fillets should be put in and the pattern blackened and finished as is customary with all master patterns, after which iron patterns should be cast

from it. It is advisable before expending too much labor on the iron patterns to prove their accuracy by placing them on gear centers and allowing them to run together. If ordinary care has been used there should be no serious trouble, but if they seem to bind at certain points, these may be eased off with a file. On the whole, however, the patterns will be found entirely satisfactory and will give good smooth running gears.

Half-elliptic Gears: As applied to a machine tool, the elliptic gear quick-return motion has one radical fault which is that, while a slow advance with a quick return is given to the tool, the cutting stroke is not made at a uniform speed but begins with a gradually retarded motion, and then, in the last half of the stroke, the speed begins to accelerate again. In order to overcome this defect and to produce a machine with a uniform motion during the entire cutting stroke, the combination of half-elliptic and spur gearing shown in Fig. 4 may be used. The half-elliptic or oval gear shown makes but one-half a revolution to each complete revolution of its eccentric driving pinion. Therefore, half of the elliptic gear may be cut away as shown. It is mounted on the same shaft with half of a regular spur gear, the pitch diameter of which is equal to the major axis of the half-elliptic gear. On the shaft with the eccentric driving pinion, an ordinary concentric pinion may be placed, the pitch diameter of which is equal to one-fourth that of the half-spur gear. This pinion is so mounted that it will engage the half-spur gear when the eccentric pinion has swung the half-elliptic gear into the position shown in Fig. 4. At this point, the eccentric pinion ceases to drive the half-elliptic gear, owing to half of it being removed. The concentric pinion now engages the teeth of the half-spur gear, picks up the load and continues to drive it through the next half revolution of the gear shaft, or until the teeth of the working half of the half-elliptic gear are again engaged by the eccentric pinion. Owing to the difference in diameters of the half-spur gear and its pinion, the latter must make two revolutions before the eccentric pinion can again engage the teeth of its half-elliptic mate.

When the eccentric pinion picks up the load it does so at the same speed at which the concentric pinion left it, due to the fact that the short segment of the axis is equal to the radius of the concentric pinion. Now as the eccentric pinion begins to swing the half-elliptic gear around, the gear will gain speed until it reaches a point where the long segment of the axis of the eccentric pinion is opposite the minor axis of the half-elliptic gear, when it has reached the maximum speed. After that, the speed of the half-elliptic gear will gradually decrease until it again reaches that of the concentric pinion, whereupon it will be once more picked up by the concentric pinion and the same cycle will be repeated.

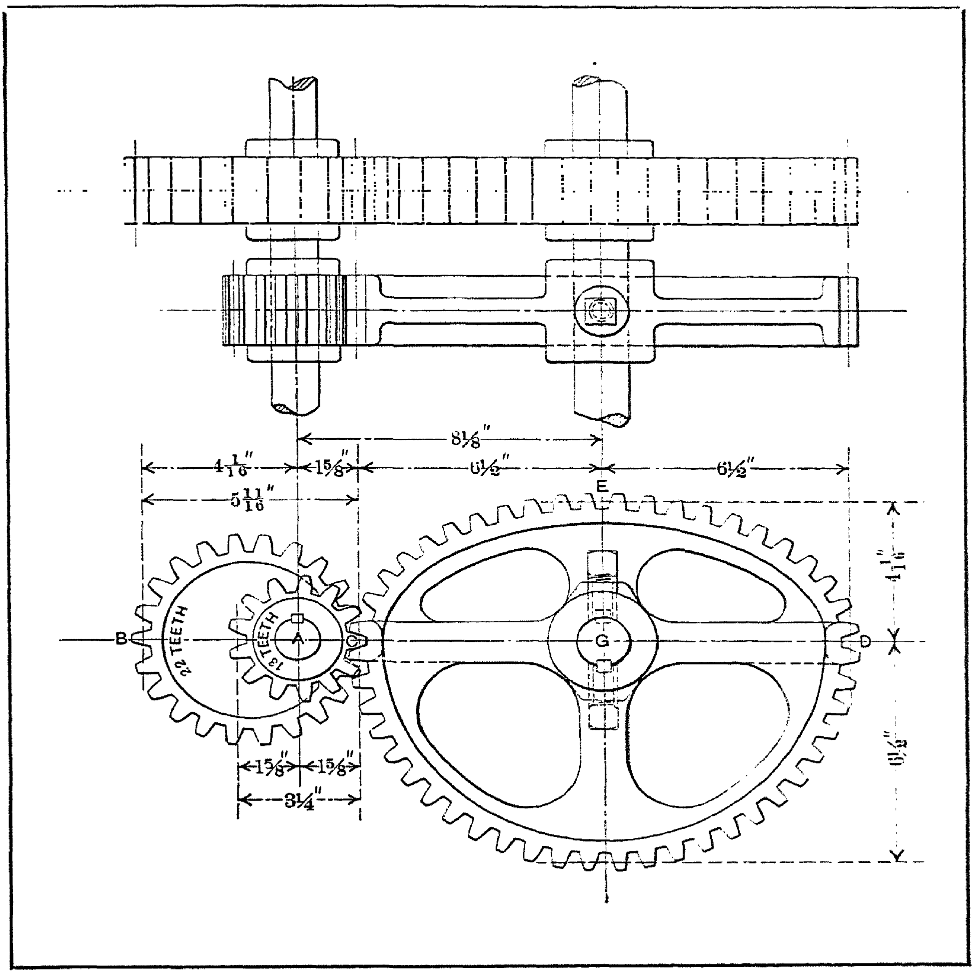


Fig. 4. Quick-return Gearing with Ratio of 2 to 1

It will be observed that for each three revolutions of the pinion shaft the half-elliptic gear shaft makes but one, and that while it takes two revolutions of the concentric pinion to cause the half-elliptic gear shaft to make one-half a revolution, the eccentric pinion will drive the half-elliptic gear the remaining half revolution while making one turn. It will also be seen that the concentric pinion drives the half-spur gear at a slow and uniform speed. After this the eccentric pinion starts to drive, the half-elliptic gear, rotating slowly at first but gaining headway, reaching the maximum and then falling back to the original slow speed. During this time the tool-head is returned with a quick motion to the starting position ready for the next cutting stroke. The ratio

of the quick return to the cutting speed must not be too great or else a jerky motion will ensue that will cause an excessive vibration in the machine. It has been found by experiment that a ratio of 2 to 1 is about the best speed at which the tool can be run, and by the combination just described this proportion is obtained with a smooth easy change from fast to slow, approaching as nearly as possible the ideal motion.

Laying out Half-elliptic Gears: The main feature of this combination of gearing is the half-elliptic eccentric pair. It may be well first to state briefly a few cardinal points that apply without change to all gears of this form. 1. The long segment (*AB* in Fig. 4) of the eccentric pinion in all half-elliptic eccentric pairs is equal to one-half the distance between the centers of the shafts. 2. The short segment *(AC)* of the eccentric pinion is equal to one-half the diameter of the concentric pinion running on the shaft with it. 3. The true diameter *(BC)* of the eccentric pinion equals the sum of its long and short segments (or $AB + AC$). 4. The major axis *(CD)* of the half-elliptic gear is equal in all cases to twice the distance between the shaft centers, less twice the short segment *(AC)* of the eccentric pinion. 5. The minor axis of the half-elliptic gear equals in all cases the distance between the centers of the shafts. 6. The elliptical gear, if complete, should have twice the number of teeth that there are in its eccentric driving pinion, and the number of the teeth in both the half-elliptic gear and the eccentric pinion should be even. 7. The shaft hole *G* of the half-elliptic gear is always placed at the intersection of the major and minor axes, or, in other words, in the exact center of the half-elliptic gear, and not at the focus, as in regular elliptic gearing.

With the foregoing rules in mind, assume 4 diametral pitch as the proper pitch for the gear teeth. As the half spur gear makes but one-half a revolution to each two revolutions of its concentric driving pinion, it naturally follows that it must have twice the number of teeth in half its circumference as are contained in the entire periphery of the concentric pinion that drives it. In other words, if the gear were a complete circle, it would have four times the number of teeth in its pitch-line that are contained in that of the concentric driving pinion. If, therefore, this circle is assumed to contain 52 teeth, then the pinion should have one-fourth that number, or 13 teeth. The pitch diameter of the larger gear would be equal to 52/4 or 13 inches, while that of the pinion would be 13/4 or 3¼ inches. As the distance between the centers of the shafts is equal to one-half the sum of the pitch diameters of the intermeshing gears running on them, it would, in this case, equal $13 + 3\frac{1}{4}$ or 8^1

Eccentric Pinion: Now consider the eccentric pinion. Its long segment must be equal to one-half the distance between the centers of the shafts; the short segment must be equal to one-half the diameter of the concentric pinion running on the same shaft with it. Therefore, the long segment will equal $8\frac{1}{8} \div 2$, or 4 1/16 inches, while the short segment will equal $3\frac{1}{4} \div 2$, or $1\frac{5}{8}$ inch. The true pitch diameter of the eccentric pinion is equal to the sum of its long and short segments, or 5 11/16 inches. This pitch diameter multiplied by the pitch of the tooth gives 4×5 11/16, or $22\frac{3}{4}$, as the number of teeth in the pitch circle. This is impossible, and as it is necessary that the number of teeth in the eccentric pinion be even, 22 teeth will be used. This will necessitate spacing them slightly farther apart.

Half-elliptic Gear: The major axis of the half-elliptic gear is the same as that of the half spur gear, or 13 inches. Its minor axis is equal to the distance between the shaft centers, or $8\frac{1}{8}$ inches. Having these figures to work with, proceed to construct the elliptic pitch-line of the gear. After having obtained the pitch-line, lay off the tops and bottoms of the teeth parallel to it and draw in the teeth, using the methods already explained for regular elliptic gears. It is essential, in laying out the half-elliptic gear, that both ends of the major axis should bisect a tooth space as shown in Fig. 4, owing to the fact that the eccentric driving pinion makes two complete revolutions to each one of the half-elliptic gear and so corresponding points on the opposite side of the elliptic gear should be constructed in the same manner; otherwise, the eccentric pinion, which should have a tooth at the end of both the long and short segment of its axes, as shown in Fig. 4, will not mesh properly with it. The eccentric pinion is simply a regular circular pinion with its shaft hole off center.

Elliptic Springs. An elliptic spring generally consists of a number of flat leaf springs so arranged that the supports are at both ends of the flat leaves and the loads applied in the center. The leaves are generally slightly curved in the making, giving them the shape of an elliptic arc, so that the load, when applied, tends to straighten the leaves. Elliptic springs may be either *half-elliptic,* also known as semi-elliptic, or *full-elliptic,* according to whether they are made up of one or two sets of curved leaves.

Elmore Process. The Elmore process is an electrolytic process for making copper tubes by depositing copper on a conducting cylinder rotating in an acid copper-sulphate bath. The surface of the conducting cylinder is prepared so that the copper will not stick so firmly that the tubes cannot be slipped off the cylinder when finished. The outer surface of the tube being deposited is kept smooth by frequent polishing during the deposition of copper. Copper sheets may be made by the same process by making

the cylinders on which the copper is deposited of large diameter, so that the tubes become large enough to be cut open and spread out.

Elongation and Reduction of Area. When a piece of material is tested for tensile strength in a testing machine, it elongates a certain amount before rupture takes place. This elongation constitutes an important quality in the material, as it indicates its toughness or the degree to which the material is likely to give warning before it will actually break. It is measured as the percentage of stretch or *elongation* occurring in a given length of the original piece; this length is frequently assumed as two inches. For example, if a test-piece 2 inches long is found to be 2¼ inches long after rupture, the elongation in two inches is said to be 12½ per cent. It should be noted that the recorded value of elongation for any test depends largely upon the original length selected for comparison, because the total elongation consists partly of a general extension which takes place mainly before the ultimate stress has been reached, and which is distributed fairly uniformly over the whole length of the piece, and partly of an elongation in the vicinity of the section where the rupture will occur, where the local elongation is much greater, and practically independent of the total length of the piece. At this point, the elongation is also accompanied by a marked contraction of cross-sectional area. The elongation at the time of rupture cannot be calculated, but, in every case, is found by actual tests.

A piece of material tested to failure in tension contracts or decreases in cross-sectional area at the point of rupture. The percentage of decrease of area in relation to the original normal cross-section is known as the *reduction of area.* For example, if the original cross-sectional area of a bar was 0.78 square inch, and the section, after the piece had been tested to failure, was 0.44 square inch, then the decrease of area would be 0.34 square inch and the reduction of area would be $0.34 \div 0.78 = 0.44$, or 44 per cent. The area of a round bar tested to destruction is usually computed from the mean of two diameters measured at right angles to each other. Brittle materials fail without appreciable deformation. Thus the percentage of elongation and the reduction of area in test-pieces of brittle materials are very small. As an example may be mentioned cast iron, which will break with practically no deformation.

Embossing. Embossing is the process of producing raised patterns or letters on metal surfaces. The term is also extended to the production of raised patterns on leather, paper, and other fabrics. Strictly speaking, the term should be applied only to the process of producing raised patterns or letters by means of

dies or plates which are brought to bear forcibly upon the material to be embossed.

Embossing and Coining Presses. Some embossing operations may be done in almost any kind of power press but the heaviest work requires a machine of special design, owing to the enormous pressures necessary for this branch of die work. These pressures range from a few tons up to 1000 or 1500 tons. In the knuckle-joint embossing press, the die is fastened to a slide which is actuated by means of powerful toggles. These presses are adapted for embossing silver, Britannia, brass, copper, etc., and the manufacture of medals, coin, jewelry, watches, silverware, etc.

Embossing Dies. An embossing die is used to form raised letters or an ornamental design, in relief, upon the surface of the work. An embossing die differs from a forming die in that the projections or designs made by it are comparatively small or shallow, and usually in the nature of relief work upon a surface, whereas a forming die gives the required shape to the work. The formation of lettered inscriptions, symbols, and decorative designs on all kinds of sheet-metal boxes and cans is done by embossing dies. A simple form of embossing die is one used for producing the circular ridges on the heads of tin cans, etc. Such a die would have one or more annular grooves and the punch would have annular ridges of corresponding size for forcing the metal into the die grooves. Embossing is commonly done in a die designed to cut, draw, and emboss the blank in one operation. An embossing die of this kind may be either a combination, a double-action, or a triple-action type, depending upon the nature of the work and the kind of press available.

Emerson Wage System. See Wage System, Emerson.

Emery. Emery is an abrasive which has been very extensively used. At one time, practically all grinding wheels were made from it, but artificial abrasives possessing superior cutting qualities are now employed for machine grinding. Emery is obtained from Naxos (an island in the Ægean Sea); from the vicinity of Smyrna, in Turkey; and from Chester, Mass. The value of emery as an abrasive depends upon the proportion of crystalline aluminum oxide which it contains, since this is the only element in emery which is hard enough to have any appreciable cutting action on metals. Naxos emery contains 63 per cent aluminum oxide; Smyrna or Turkish emery, 57 per cent; and Chester emery, 55 per cent.

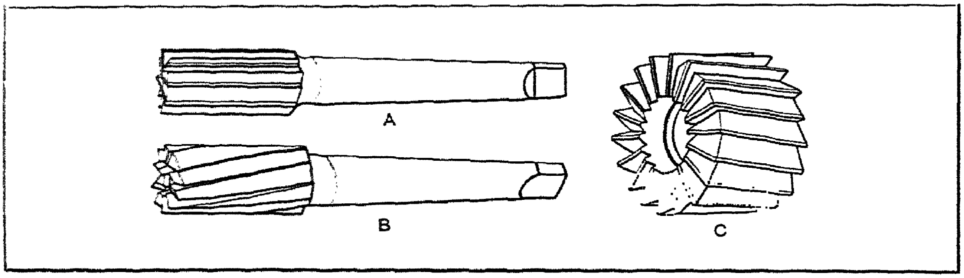
E.M.F. This is an abbreviation for electromotive force. The abbreviation *emf* has been adopted as the American Standard. See Electromotive Force.

Enamelite. Enamelite is the trade name originally given to a preparation used for the local hardening of steel. See Localcase and Localhard.

End Angle of Hob. See Hob End Angle.

End Milling. Surfaces are frequently machined by end-mills when it would not be feasible to use a cutter mounted on an arbor. The surface is milled by the radial teeth on the end as well as by the axial teeth, as the work is traversed at right angles to the cutter.

End-Mills. End-mills, as shown at *A* and *B*, are provided with teeth both on the cylindrical surface and on the plain end surface; hence, they can cut in an endwise as well as in a sidewise direction. End-mills may be provided either with a solid shank by which they are driven, or with a hole through them in which



End-mills

an arbor fits which drives the mill. This latter type, shown at *C*, is known as a *shell end-mill*.

End-mill Flutes: Theoretically, a right-hand cutter should have right-hand spiral flutes, as the teeth then have positive rake. Although the right-hand flutes tend to pull the cutter out of the socket when used for side-milling, this disadvantage does not outweigh the advantage of having the cutter teeth made with positive rake. It is good practice to hold the cutter firmly in the socket by means of a threaded rod which passes through the spindle and engages the end of the cutter shank, and thus draw the cutter firmly into the spindle socket.

The fact that a left-hand spiral on a right-hand mill tends to push the cutter firmly into the socket is often considered a greater advantage than the positive rake of the right-hand spiral on a right-hand cutter. This applies only when the cutter is used for milling slots where a considerable number of teeth along the body of the mill are engaged. If the mill is used as an end cutter only, then the teeth on the right-hand cutter should be right-handed in order to have a positive front rake. Some manufac-

turers of milling cutters prefer, for ordinary use, end-mills having straight teeth.

Energy Conservation. See Conservation of Energy.

Energy in Chemistry. The chemical combination of two or more elements could not be effected if there were in the universe nothing but matter. The combination of equal parts of hydrogen and chlorine is merely a mechanical mixture until it is exposed to light, and a combination of copper filings and sulphur is only a mechanical mixture until it is exposed to heat. In each case, however, an entirely different substance is obtained. This shows that there is present in the universe a power to perform work, called *energy*. It may manifest itself in the form of light, heat, electricity, etc. It may be changed from one form to another, but, like matter, it cannot be destroyed. In chemistry, energy effects changes in the composition of a substance, or in chemical changes.

Energy in Mechanics. A body is said to possess *energy*, in a mechanical sense, when it has the capacity of doing work—that is, of overcoming a resistance through a distance. In general, energy is something that is given to a body by doing work upon it, as when a weight is raised or is given a rapid motion, or when a spring is compressed; the energy, in turn, is given out when the body itself performs work. Energy is, therefore, sometimes defined as stored work. It is expressed in foot-pounds, the same unit that is used to express work. Energy is either potential or kinetic.

Potential Energy: Potential energy is the power of doing work possessed by a body in virtue of its position or condition. A compressed spring, a raised pile driver, a pendulum at the end of its stroke, and a head of water have the capacity of doing work and are therefore stored with potential energy.

Kinetic Energy: Kinetic energy is the power of doing work possessed by a body on account of its motion. A moving railroad train, a flywheel, a current of air driving a windmill, a falling body, all possess kinetic energy. The kinetic energy of a body is obtained by multiplying one-half its mass by the square of its velocity in feet per second.

Engine. According to modern usage, the word "engine" is generally assumed to mean some type of prime mover, such as a steam engine or internal combustion engine. (See type such as Steam Engine, Diesel Engine, etc.) In the early stages of mechanical developments particularly, almost every mechanical device, especially if intended for the transmission of energy, was called an engine, and this broader usage of the term has survived in a few instances, as for example, engine lathe, dividing engine, dental engine, etc.

Engineering. The field of work wherein scientific knowledge is applied to industrial problems has become known as the "field of engineering." Originally the term engineering was used to designate the design, construction, and operation of industrial works, but it has been extended to cover practically everything in the way of industrial work, including the problems of humanity so far as they are affected by modern industrial methods.

Engineer's Chain. The engineer's chain used in surveying has 100 links, each 1 foot long, making the total length of the chain 100 feet. Every tenth link is provided with a brass tag marked to indicate the number of the links from the end, and the middle of the chain is marked with a round tag. Each end-link is provided with a handle, and the zero point or end of the chain is at the outside edge of the handle. Measurements made with the chain are liable to be inaccurate unless care is taken, because of sagging at the center due to its weight, and also to changes in length caused by wearing at the joints. The length of the chain is adjustable by means of a screw and nut in one of the handles, permitting the length of the end link to be changed. This corrects the error in the total length of the chain, but as the correction is made at one end only, the error is still present in the remainder of the chain. Owing to the wear and other disadvantages of measuring chains, they are gradually being displaced by heavy steel tapes. The metric chain has 100 links, each 20 centimeters long, the total length of the chain being 20 meters. See also Gunter's Chain.

Engine Lathe. A name commonly applied to a general-purpose metal-working lathe of the hand-manipulated type found in practically all machine shops. Such lathes are called *engine* lathes because during the early stages of lathe development, the term engine was applied quite generally to different classes of mechanism. See Lathe Classification.

Engines, Aircraft. A review of the specification data of 116 types of American aircraft engines built by 16 companies shows that 66 per cent were of the radial type, 19 per cent were of the horizontally opposed type, 10 per cent were of the inverted in-line type and the balance were mostly of the inverted V-type. All of these engines were air cooled except for one type which was water cooled and one type which was liquid cooled. The number of cylinders ranged from three in the small, sport, pleasure type to fourteen in the high powered military engines. Cruising horsepowers ranged from 30 to 900. Weight per cruising horsepower ranged from 1.82 to 4.83 pounds with a majority having a weight per horsepower of 2.5 pounds or less. The octane rating of the fuel required ranged from 65 to 100. About half of these engines required a fuel of 80 minimum octane rating.

Engines, Passenger Automobile. A review of specification data for 38 types and sizes of American engines built by 8 companies for passenger automobiles shows that maximum brake horsepower for six-cylinder engines ranges from 78 to 120 H.P. with a majority in the range from 85 to 100 H.P. For eight-cylinder cars maximum brake horsepower ranged from 60 to 160 H.P. with a majority in the range from 105 to 140. Most of the horsepower ratings were given for rotational speeds in the range of 3400 to 3700 R.P.M., although a few were rated at 3800 and 4000 R.P.M. In the 6-cylinder engines piston diameters ranged from 3 to 3½ inches with the majority in the range from 3¼ to 3 7/16 inches. The length of piston strokes in 6-cylinder engines ranged from 3¾ to 5 inches with the majority within the range from 4⅛ to 4⅜ inches. In the 8-cylinder engines piston diameters ranged from 2.6 to 3½ inches with the majority in the range from 3¼ to 3½ inches. Piston strokes ranged from 3.2 to 4⅞ inches with the majority in the range 4¼ to 4½ inches.

English Gear-Bronze. This is an alloy composed of 88.7 per cent of copper, 11 per cent of tin, and 0.3 per cent of phosphorus. The phosphorus is introduced into the alloy in the form of phosphor-copper containing 15 per cent of phosphorus, so that the working formula for the preparation of the alloy is: Copper, 87 per cent; tin, 11 per cent; phosphor-copper, 2 per cent. When properly made, this bronze will have an ultimate strength of 48,000 pounds per square inch, a yield point of 26,000 pounds per square inch; a specific gravity of 8.83; and a Brinell hardness number of 82. The elongation is from 17 to 18 per cent in two inches, and the reduction of area, 18 per cent.

English Legal Standard Wire Gage. This gage is used in England for all wire. It is also known as the Imperial Wire Gage, and Standard Wire Gage.

Engraving Machines. Engraving machines are designed to reproduce the form of a pattern or model on the part to be engraved, by means of a mechanism which transmits the movement of a tracing point to a suitable cutting tool. In the operation of the machine, the tracing point is made to follow the pattern or model, usually by guiding it with the hand. There are two general types of engraving machines. On one type the tool does not revolve, but is drawn across the work so that it operates the same as a planing tool. The angular position of the graver or tool may be varied to secure different effects, and the tool-holder may also be turned on some machines so that the graver will be kept facing the changing direction of the cut, but the tool does not revolve continuously. Engraving machines of this type are extensively used by jewelers, etc., for engraving letters on silver-

ware, name-plates, ornamental designs, and for similar operations. Engraving machines of the second class or type mentioned are equipped with rotating cutters. They are adapted more especially to the engraving of dies, steel stamps, etc., and, in some cases, for special manufacturing operations.

Engraving machines may be further classified according to the form of mechanism utilized for reproducing the pattern or model on the engraved part. Many of the types intended more particularly for engraving letters or ornate designs on nameplates, dies, silverware, etc., have a pantograph mechanism for reproducing the pattern or model on a reduced scale. Other machines of the reducing type, or those using a model that is considerably larger than the design or form to be engraved, are so arranged that the necessary reduction between the movement of the tracing point which bears against the pattern, and the tool or cutter is obtained by simply attaching the tracer and cutter head to a lever at distances from the pivot of the lever proportional to the reduction required between the pattern and engraved part. There is still another type of engraving machine which does not have a reducing mechanism, but which operates direct, in that the tracing point bears against a model corresponding in size to the impression or surface to be engraved, and this tracing point guides the cutting tool by a direct connection with the cutter spindle or the member in which it is mounted.

Entropy. In thermodynamics, especially in dealing with steam, the change in entropy or in the "condition" of the water or steam is frequently referred to. The change in entropy, which results when the required amount of heat to raise one pound of water from 32 degrees F. to the boiling point (212 degrees F.) is added, is called the "entropy of the water"; the change in entropy during evaporation, that is, the heat of evaporation divided by the absolute temperature of the boiling point, is called the "entropy of evaporation"; and the entropy of the water plus the entropy of evaporation is called the "entropy of steam." The entropy of water is approximately equal to the quotient of the heat added to one pound of water to raise its temperature from 32 degrees F. to 212 degrees F., divided by the average of these two temperatures above absolute zero.

Epicassit. Epicassit is a material which is used for coating iron or steel to protect the metal against corrosion. Epicassit consists of pure tin or of lead and tin in various proportions; an alloy of lead, tin, and zinc is also used with satisfactory results. The metal alloys are reduced to a powdered condition, and this powder is mixed with so-called *epicassit fluid* to a consistency of a thick creamy paint, which is applied with a thick bristle brush, and then melted on the surface to be coated by heating the article.

Any clean source of heat may be employed for the amalgamation, such as a blow-torch or a clean fire, or an oven. In making local repairs of vats, tanks, etc., or in entirely recoating worn surfaces, epicassit is particularly useful, as it avoids the necessity of dismantling the equipment, shipping it to the dipping plant, and then remounting it.

Epicyclic Gearing. An epicyclic or planetary gear train consists of a number of meshing gears, of which at least one revolves around a central gear, at the same time rotating about its own axis, so that the arm or bracket supporting such planetary gear, or gears, is given a definite speed of rotation by the driving gears. When the arm or bracket is the driving member of the combination, it imparts a definite speed to the driven gear, any intermediate gears or pinions simply acting as members for the transmission of motion between the principal parts—the driving and driven members of the combination. The arrangement offers possibilities of securing high speed ratios with comparatively few gears, compactly arranged. It lends itself to many transmission problems that would otherwise be solved with difficulty and require cumbersome gearing. Adaptable and convenient as are epicyclic trains, their use has been largely limited to certain types of speed reducers, and special, intricate machines or mechanisms.

Epicycloid. An epicycloid is a curve traced or described by a point located on the circumference of a circle which rolls on the outside of the circumference of another circle. If the moving circle rolls on the inside of the periphery of another circle, a point on the circumference will trace or describe a *hypocycloid.* These mathematical curves have mechanical importance, because the teeth in the cycloidal system of gear teeth are formed according to these curves.

Equaling Files. This is a type of file that is made from mill sections and is nearly of blunt form, but has a very slight curvature extending from the point to the tang. These files are double-cut and mostly bastard. Equaling files are used for general shop work, but are seldom employed except for fine toolmaking.

Equalizing Dog. In using a double-ended dog, care should be taken to adjust the driving pins so that there will be an equal pressure on each side. To avoid careless adjustment of the driving pins, what is known as an "equalizing dog" is sometimes used. This merely consists of two V-shaped clamps held together by bolts on opposite sides of the work and having extension driving ends. By adjusting the clamping bolts, the ends are brought firmly into contact with the driving pins. A convenient method

of equalizing the pressure on the pins, when a double-ended dog is used, is by means of an auxiliary plate into which the driving pins are inserted. This plate is attached to the front of the regular faceplate by means of bolts or studs which are screwed solidly into the regular faceplate but fit loosely into slots of the driving plate. These slots are radial and in line so that if one driving pin is subjected to greater pressure, when first starting a cut, this excess pressure causes the driving plate to shift so that the pin of the opposite side is automatically adjusted.

Equalizing Sets. Flywheel motor-generator equalizing sets perform the function of equalizing the load on a generating plant by taking care of the high peaks caused by fluctuating loads, such as mine hoists, etc. They usually consist of an induction motor and one or two direct-current generators with an accurately balanced cast-steel flywheel swung between them, and one or two direct-connected exciters overhung at the ends of the set. The wheel is used to store the energy when the load is light, returning it to the system when the peaks come on. The induction motor is of the phase-wound collector-ring type with a regulator in the secondary circuit so arranged that, when the supply of current to the motor increases to more than a predetermined amount, resistance is automatically inserted in the secondary motor circuit, which has the effect of limiting the current taken by the motor, and thus allowing the excess energy to be supplied by the flywheel.

Equations. An equation is a statement of equality between two expressions; thus, $5x = 105$ is an equation. Equations are used for the solution of mathematical problems. An equation is said to be of the *first degree* if it contains the unknown in the first power only. For example, $3x = 9$ is an equation of the first degree, because the unknown quantity x is in the first power. An equation which contains the unknown quantity in the second, or first and second, but no higher power, is called a *quadratic equation.* Thus, $x^2 + 3x = 18$ is a quadratic equation. An equation which contains the unknown quantity in the third power is called a *cubic equation.* Thus, $x^3 + 3x^2 + x = 22$ is a cubic equation. The solving of equations involves algebraical operations. See also Chemical Equation.

Erg. The erg is the *unit of work* in the centimetergram-second (C.G.S.) system, also frequently known as the *absolute* system of measurement. An erg equals one dyne-centimeter, the dyne being the unit of force in the C.G.S. system, and being equal to 1/981 gram. The unit of power is derived from the erg, the unit of power being one watt, which is equal to 10,000,000 ergs per second.

Erichsen Value. The term "Erichsen value" as applied to sheet metal is a factor used to indicate the workability of sheet metal. The test is conducted by supporting the sheet on a circular ring and deforming it at the center of the ring by using a spherical shaped tool. The depth of the impression or cup, in millimeters, required to obtain fracture is the Erichsen value of the metal. Erichsen standard values of sheet metals are furnished by some manufacturers for various sheet thicknesses. See Sheet-metal Testing.

Escapements. An escapement may be considered as a form of ratchet mechanism having an oscillating double-ended pawl for controlling the motion of the ratchet wheel by engaging successive teeth. Escapements are designed to allow intermittent motion to occur at regular intervals of time. As applied to a pendulum clock the escapement serves two purposes, in that it governs the movement of the scape wheel for each swing of the pendulum and also gives the pendulum an impulse each time a tooth of the scape wheel is released. An escapement should be so arranged that the pendulum will receive an impulse for a short period at the lowest part of its swing and then be left free until the next impulse occurs. One of the earlier forms of escapements was known as the "anchor" or "recoil" escapement. With this type, the pendulum was never free, but was controlled by the escapement throughout the swing. To avoid this effect, the Graham "dead-beat" escapement was designed and has been extensively used. When the escapement is in action, the pallets (two ends of the double-ended pawl) alternately engage the teeth of the scape wheel, which revolves intermittently. In designing an escapement of this type, the pallets are so located as to embrace about one-third of the circumference of the scape wheel. One of the features of the dead-beat escapement is the effect which friction has on its operation. During each swing of the pendulum, there is a rubbing action between the points of the scape wheel teeth and the surfaces of the pallets, so that the pendulum is retarded constantly by a slight amount of friction. This friction, however, instead of being a defect, is a decided advantage, because, if the driving force of the clock is increased so that the impulse on the pallets becomes greater, the velocity of the pendulum tends to increase, but this effect is counteracted by the frictional retardation caused by a greater pressure of the teeth of the scape wheel on the faces of the pallet.

Etching. A common method of etching names or simple designs upon steel is to apply a thin, even coating of beeswax, or some similar substance which will resist acid; then mark the required lines or letters in the wax with a sharp-pointed scriber, thus exposing the steel (where the wax has been removed by the

scriber point) to the action of an acid, which is finally applied. The proper application of the ground which is used to protect the parts from the action of the corroding fluid is very important. For general purposes, beeswax of the proper consistency is excellent, and it can be applied easily in any desired thickness. Before applying the wax, it is important that the surface be thoroughly clean and absolutely dry, and the difference in temperature between the wax and the article to be etched should be slight. If it is necessary to dip the piece into melted wax, the article should be kept immersed for a few moments until it acquires the same temperature as the molten wax. If there is a film of oil on the surface to be coated, the wax will cover it but not adhere, and in consequence the etching fluid will run under the wax and produce a smear or blur. The same effect is produced by moisture, except that in this case the blur is likely to be worse, as there is an affinity between water and etching fluid which causes spreading.

Etching Acids. The following fluids have been tried on the various substances for etching and found to work satisfactorily: *Iron and Steel:* Hydrochloric acid (full strength). *Brass:* Nitric acid. *Copper:* A mixture containing 2 parts of nitric acid and 1 part sulphuric acid. *Silver:* Nitric acid, 3 parts, water, 1 part. *Gold:* A mixture containing 1 part of nitric acid and 3 parts of hydrochloric acid. This mixture should be prepared just before being applied and should be used warm, under a hood or fume closet. *Platinum:* The same mixture as that used for gold. *Lead:* Nitric acid. *Aluminum:* A 10 per cent solution of caustic soda or potash. *Zinc:* A mixture containing equal parts of hydrochloric acid and water, used warm. *Glass:* Hydrofluoric acid. The article may be immersed in the liquid acid for a few minutes or it may be exposed to the fumes from five to fifteen minutes. Extreme caution should be used in handling this acid, using rubber gloves for the hands and a lead or hard rubber container for the acid. Contact with the skin will cause severe burns. All of these acids may be used full strength and will act instantly, but if the etching is to be of considerable depth most of them may be diluted with water before applying. This will require more time, but will produce a cleaner cut. The exception to this is the mixture for gold and platinum, which must always be used full strength and applied as warm as the melting point of the wax will permit.

Etching, Electrical. See Electro-etching.

Etching Resists. Various acid-resisting materials are used for covering the surfaces of steel rules, etc., prior to marking off the lines on a graduating machine. When the graduation lines

are fine and very closely spaced, as on machinists' scales which are divided into hundredths or sixty-fourths, it is very important to use a thin resist that will cling to the metal and prevent any under-cutting of the acid; the resist should also enable fine lines to be drawn without tearing or crumbling as the tool passes through it. One resist that has been extensively used is composed of about 50 per cent of asphaltum, 25 per cent of beeswax, and, in addition, a small percentage of Burgundy pitch, black pitch, and turpentine. A thin covering of this resisting material is applied to the clean polished surface to be graduated and, after it is dry, the work is ready for the graduating machine. For some classes of work, paraffin is used for protecting the surface surrounding the graduation lines which are to be etched. The method of application consists in melting the paraffin and raising its temperature high enough so that it will flow freely; then the work on which the graduating is to be done is held at a slight angle and the paraffin is poured on its upper edge. As the melted paraffin flows across the surface of the work, the latter will be covered with a thin protective coating.

Etch Test. The etch test is a method for testing metals by microscopic inspection. The test specimen is ground or polished and then etched by a suitable acid or other etching fluid for a sufficient period to develop the structure of the metal.

Eutectoid Steels. A steel composed wholly of pearlite is called eutectoid, and contains about 0.90 per cent of carbon. Steel with a lower carbon content is called hypo-eutectoid and it consists of pearlite and "free" or "excess" ferrite, the amounts depending upon the carbon content. Steel containing more than about 0.90 per cent is called hyper-eutectoid and it consists of pearlite and free cementite. Eutectoid steel is also known as saturated steel.

Evaporation Rate. See Rate of Evaporation.

Ewart Chain. Same as Link-belt.

Exciters. Almost all synchronous machines are dependent on an external source of direct current for the magnetization of their fields, and the machines furnishing this excitation are generally termed *exciters*. The exciters may be either direct connected to the main generators or driven separately by prime movers or motors.

Exhaust System. The term "exhaust system" as applied to certain types of low-pressure industrial pneumatic systems is not accurately defined but usually is interpreted as including dust collecting, fume removal and low-pressure conveying systems. Heating, ventilating and air conditioning systems are definitely

excluded. A general characteristic of exhaust systems is that the fluid flowing through the piping is not homogeneous. It is a mixture, usually of air as the parent fluid, carrying solids in suspension or vaporous or gaseous materials. Broadly, an exhaust system is a pneumatic conveying system even though its primary purpose may be quite different from the mere transportation of materials.

Expanded Metal. The term "expanded metal" is applied to sheet metal which has been stretched or expanded to form a screen, by first splitting the solid sheet intermittently so that the entire sheet has a series of closely spaced parallel cuts, to permit expanding it laterally to form open screen work. Thus, as the sheet is stretched edgewise the numerous slits open and the metal between them forms a screen of diagonal pattern. Expanded metal screens are made from stock of various thicknesses and are used for concrete reinforcing, metal laths, machine guard screens, and for various other purposes.

Expanding-Band Clutch. This is a clutch similar to the contracting-band clutch, except that its action depends upon the expansion of a band or ring which, when expanded, grips the inside of a drum surrounding it, and thus transmits power.

Expansion. Practically all substances expand when heated. The expansion of solid bodies in a longitudinal direction is known as the *linear expansion.* The expansion in volume is called the *volumetric expansion;* this latter equals three times the linear expansion.

If the amount that a steel rod lengthens when its temperature is increased one degree F. is known, the expansion for a greater increase of temperature may be determined readily. In engineering handbooks tables will be found which give the linear expansion of different metals and other materials, per unit of length, for an increase in temperature of one degree. This figure which is called the *coefficient of expansion,* is obtained by dividing the amount that a rod of given length expands after a one-degree rise in temperature, by the original length of the rod. For instance, if a rod 120 inches long expanded 0.0008 inch due to a one-degree F. rise in temperature, the coefficient of the linear expansion, or linear expansion per unit of length per degree F., would equal $0.0008 \div 120 = 0.00000666$. Therefore, a rod made of this particular material would increase 0.00000666 of its length for each rise in temperature of one degree F. Hence, the total amount of linear expansion may be determined by the following rule:

Rule: Multiply the length of the rod or other part by the coefficient of expansion for that particular metal, and multiply the

product by the difference between the original temperature and the temperature after heating.

Expansion, Adiabatic. See Adiabatic Expansion and Compression.

Expansion Arbor. This is a type of arbor the diameter of which can be decreased or increased within certain limits. Its diameter may be varied to fit varying diameter holes in parts to be machined, thereby reducing the number of arbors required for a given range of work. Many different designs of expansion arbors are found in machine shops.

Expansion Bends. For low-pressure steam and exhaust mains, expansion joints of any suitable standard make may be used to take up or relieve the strains on a piping system, but for high-pressure steam mains, it is customary and advisable to use expansion pipe bends made up of full-weight or extra-heavy steel or wrought-iron pipe. When the steam main is of considerable length, it is advisable to divide the expansion between different sections of the piping system, anchor the main rigidly at a point near the middle of each section, and provide an expansion bend in each section. The amount of expansion that can be taken care of by an expansion bend of wrought-iron or steel pipe depends upon the shape of the bend, the mean radius of the bend, the outside diameter of the pipe from which the bend is made, and the amount of straight pipe allowed between the arcs or curved portions of the bend.

Expansion Bolt. An expansion bolt is so designed that it can be expanded in a hole in which it is inserted. The expansion may be produced by a screw which enters and expands a split sleeve. Such bolts frequently are used for holding parts to brick, stone, or concrete floors or walls. The expansion part of the bolt enters the hole in the brick, stone or concrete and is then expanded, thus holding the bolt firmly. Expansion bolts are intended especially for "blind holes" in materials which require plain or untapped holes.

Expansion Fits. The term "shrink" or "shrinkage" fit commonly is used when a ring-shaped outer member is heated and expanded in order to obtain a very tight fit between the outer and inner parts as the outer member shrinks around the hub or inner member. For some classes of work this process is reversed—that is, the inner part is *contracted* by using dry ice to lower its temperature; then a tight fit is obtained as the inner part expands in the outer member. The temperature of dry ice is about 109 degrees F. below zero; consequently, it may be used for contracting metal parts before inserting them into the holes or recesses. For example, this method has been applied in assembling cast-iron

sleeves or liners into engine cylinder block castings. The liners are ground to a diameter that will provide a tight fit when they expand into the cylinder bores. They are placed in a dry ice refrigerator for 16 minutes, during which time they shrink about 0.006 inch in diameter. They are then inserted quickly into the cylinder bores and soon expand to provide a tight fit.

To cite another example, dry ice has been used in assembling alloy valve seat rings into cylinder blocks. The rings remain in the dry ice refrigerator from 6 to 12 minutes and attain a temperature of at least 90 degrees F. below zero. The resulting shrinkage makes it possible to insert them readily into the recessed holes of the cylinder block. See Shrinkage Fits; Forced Fits, Driving Fits.

Expansion, Isothermal. See Isothermal Expansion and Compression.

Expansion Joints. In the design of a system of piping, either for power or heating, allowance must be made for the strains due to expansion and contraction. This expansion usually amounts to about 1½ inches per 100 feet of pipe. The expansion and contraction is provided for by the arrangement of the piping, in most cases, but, for long straight pipe lines, expansion joints must be provided. There are three methods commonly used for taking up the expansion in pipes: 1. By using so-called sweep or expansion bends in place of cast-iron elbows, and arranging the piping so as to provide the maximum amount of flexibility or spring. 2. By the use of swing or swivel joints. 3. By the use of expansion or slip joints.

Expansion Ratio. See Ratio of Expansion.

Exponent. In mathematics, an exponent is the figure or symbol which indicates the power to which the quantity to which it is affixed is to be raised. In the expression 5^3, the exponent or small figure (^{3}) indicates that 5 is to be raised to the third power; the expression A^n indicates that A is to be raised to the nth power, n being the exponent.

Export Trade Terms. See Trade Terms.

Extensometer. The extensometer is an instrument which may be used in making very careful measurements of elongation, as in determining the elastic limit of materials. With such an instrument it is easy to determine when the load and elongation cease to be proportional. Shortly after this point is reached, the instrument is removed to prevent injury when the specimen breaks.

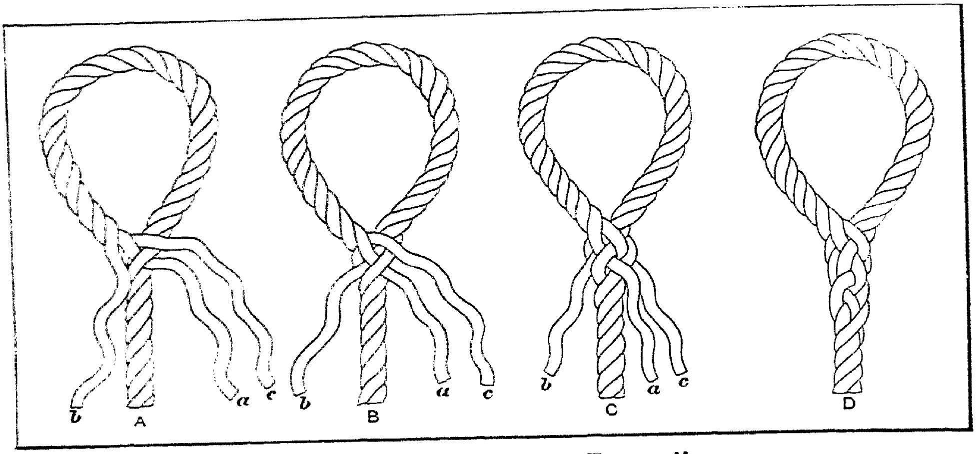
Extractors, Oil. See Chip and Oil Separators.

"Extra Heavy." When applied to pipe, the term "extra heavy" means pipe thicker than standard pipe; when applied to valves and fittings, the term indicates goods suitable for a working pressure of 250 pounds per square inch. See also Pipe Schedule Numbers.

Extrusion of Metals. The extrusion process is a method by means of which shapes of fairly plastic metals are produced by forcing the metal, which is usually heated, under high pressure through an aperture of the shape to be produced. In this manner, a continuous bar or pipe of the cross-section of the aperture or die is produced. Lead and tin can be extruded at comparatively low temperatures (250 degrees F.), while copper requires a temperature of about 1750 degrees F. The advantages of the extrusion process are that it permits parts of unusual cross-section to be produced cheaply. On account of the high pressure under which the metal is extruded, its structure becomes more compact and its strength is increased. The surfaces are smooth and free from flaws and other defects. Sometimes metals are extruded at atmospheric temperatures, in which case a higher pressure must be used, but the metal will be more condensed and the grain refined, adding to its strength, hardness, and toughness. It requires, however, five times the pressure to extrude aluminum at 70 degrees F., as compared with the pressure required at 600 degrees F. Small gears, ratchet wheels, racks, padlocks hasps, and other special shapes are extruded in long bars which are afterwards sawed up to give the pieces their required thickness. The extrusion process is used extensively for making collapsible tubes of tin and lead, for containing dentifrice, artists' colors and other preparations. In the extrusion of metals it is natural that lead should have been the one first used, as this is the most plastic of metals. The other metals extruded are aluminum, zinc, copper, and brass, as well as various other alloys.

Eyebolt. This is a bolt threaded at one end and provided with a loop or eye at the other, so that it may be attached to a ring or hook.

Eye-Splice. When a loop is formed at the end of a rope by splicing the free end to the main or standing part of the rope, this is known as an *eye-splice*. The end of the rope is first unlaid about as far as it would be for making a short splice. After bending the end around to form a loop of the required size, the middle strand *a* (see diagram) is tucked under a strand on the main part of the rope, as illustrated at *A*. The strand *b* is next inserted from the rear side under the strand on the main part which is just above the strand under which *a* was inserted. Since strand *b* is pushed under the strand on the main part from the



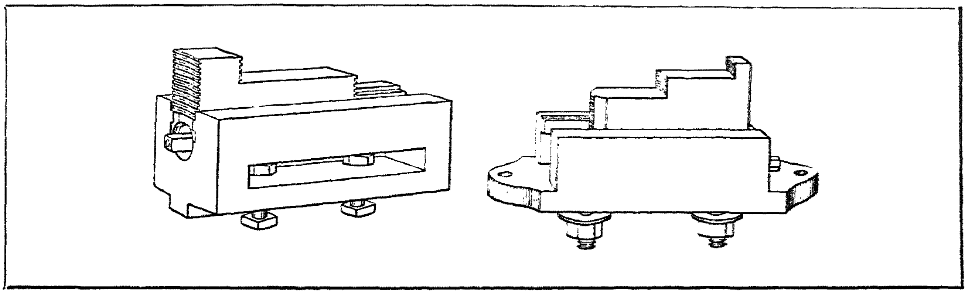
Method of Making an Eye-splice

rear side, it will come out at the point where strand *a* went in, as illustrated at *B*. The third strand *c* is now passed over the strand under which strand *a* was inserted, and then under the next successive one, as illustrated at *C*. These three strands are next pulled taut and then about one-third of the fiber should be cut from them; they are next tucked away by passing a strand over its adjoining one and under the next successive strand. The reason for cutting away part of the fiber or yarns is to reduce the size of the splice and give it a neater appearance. By gradually thinning out the fiber, the over-lapping strands may be given a gradual taper, as indicated at *D*, which shows the completed eye-splice.

F

Face Angle of Bevel Gear. There are two methods of designating the face angle of a bevel gear. According to one method, this is the angle between the top of a tooth and a plane perpendicular to the axis of the gear. The term according to the other method means the angle between the top of a tooth and the axis of the gear or one-half the included angle of the blank.

Face Cam. This is a cam in which a groove for guiding the roller of the cam follower is cut into the flat face of a cylindrical disk. A face cam has an action similar to that of a disk cam, except that the face cam guides the follower positively in both the forward and reverse direction, as the roller engages a slot instead of the periphery of the cam.



Two Designs of Faceplate Jaws

Face Milling. This term as generally used, means the production of a plane surface by the teeth of a milling cutter which operate in a plane that is at right angles to the axis of the cutter.

Faceplate Jaws. Special faceplate jaws (see illustration) may often be used to advantage for holding work on large lathe faceplates, and they are also frequently applied to the tables of vertical boring mills. Three or four of these jaws are bolted to a faceplate or a machine table, as the case may be, thus converting it into a kind of independent chuck. Faceplate jaws are held in position by means of square-headed bolts that engage T-slots in the faceplate or table, and they are additionally held and aligned, in most cases, by a tongue that fits into the T-slot.

Face Width. In spur gearing, the "face" or face width is the length of the teeth or the distance across the gear rim measured parallel to the shaft upon which the gear is mounted. In bevel gearing, the face or face width is the width of the tooth measured on a line parallel to the pitch line.

Facing Materials. Facing materials are applied to the surfaces of foundry molds to improve the appearance of the casting by preventing the fusion of the metal and sand. There are many patent facing materials on the market. Dry plumbago applied with a soft brush is a common facing for green sand work, while a blacking mixture composed of lead, charcoal, and blacking, mixed with clay water, is extensively used for dry sand and loam molds.

Facing Sand. In molding, the sand that is sifted or riddled over a pattern to form the face of the mold is known as *facing sand.* It may be backed up with coarser floor sand. The facing may be of sifted floor sand or of an entirely different grade.

Factoring. In mathematics, factoring is the process of obtaining the factors of a number or quantity; that is, the numbers or quantities which, when multiplied together, will give as a product the given number or quantity. Thus 3 and 11 are factors of 33 because $3 \times 11 = 33$.

Factor of Evaporation. The factor of evaporation is the ratio between the number of heat units required for evaporating one pound of water of a given feed water temperature into steam of a given pressure, to the number of heat units required for evaporating one pound of water from a temperature of 212 degrees F. into steam at atmospheric pressure.

Factor of Safety. It is the practice among most engineers engaged in the designing of machinery to base working stresses for given materials and given classes of work, either upon their own experience or upon the observation or successful experience of others, and so long as the quality of the material remains unchanged, and the service does not vary in character, this method is satisfactory. New conditions, for which precedent is lacking, are, however, constantly arising, and materials of different qualities, either better or cheaper, for which the safe working stresses have not been determined, are introduced. The designer is then compelled to determine the proper stress for the work in hand by using a so-called "factor of safety." The name "factor of safety" is misleading, for several reasons. In the first place, it is not a "factor" from a mathematical point of view, but is, in its use, a divisor, and in its derivation, a product. In order to obtain the safe working stress, the ultimate strength of the material is

divided by the factor of safety, and, in order to obtain this factor of safety, several factors, which, in turn, depend upon the qualities of the material and the conditions of service, are multiplied together. If the ultimate strength of a material like machine steel is 60,000 pounds per square inch and it is subjected to a load of 10,000 pounds per square inch, a factor of safety of 6 is used: that is, the ultimate strength of the material is six times as great as the load to which the material is subjected in service.

Fahrenheit Thermometer. The thermometer that is most commonly used by the English speaking peoples is the *Fahrenheit thermometer* on which the freezing point of water is located at 32 degrees and the boiling point of water (at atmospheric pressure) at 212 degrees. This thermometer scale was probably the first of the three adapted thermometer scales introduced, it having been named after its inventor, a German scientist, who proposed this scale in the early part of the eighteenth century. The Fahrenheit (F.) scale is, as a rule, not used for scientific or electrical work; in that case the centigrade scale is almost exclusively used in all countries.

$$\text{Degrees Centigrade} = \frac{5 \times (\text{degrees F.} - 32)}{9}.$$

Fairbairn Crane. This is a special type of pillar crane supported and pivoted at the foundation only, in which the column and the boom are built in one piece, generally of a box section formed of angles and plates.

Falling Bodies. See Gravity.

Fan Blower. A fan blower is a special form of ordinary ventilating fan adapted commonly for working pressures up to one pound per square inch, although special types may be constructed for higher pressures. The fan blower is employed principally for forges and cupola furnaces.

Fan Brake. A fan brake is a form of absorption dynamometer sometimes used when testing high-speed machinery, such as automobile engines. The fan brake consists of a number of arms keyed to the shaft of the engine, to which flat plates are attached. When such a brake has been properly calibrated, by measuring the power required to revolve it at various speeds, it is very satisfactory. The power absorbed varies as the cube of the speed.

Fans. Fans are used for a number of applications in industrial work. Besides their use for heating and ventilation, they are employed for exhausting dust from polishing and grinding rooms, in which case they are generally connected directly with ducts leading from a hood over the polishing and grinding wheels;

they are also used for exhausting shavings from wood-working machinery, and for many similar purposes in various industries. There are two types of fans in common use: (1) the centrifugal fan, often called a "blower," and (2)the disk fan or propeller.

Farad. The unit of capacity in electricity, as adopted by the International Electrical Congress, in Chicago, 1893, and later made a legal unit for electrical measures in the United States by Act of Congress, July 12, 1894, is the *farad.* This is the capacity of a condenser charged to a potential of one volt by one coulomb of electricity.

Faraday. See under Electrochemical Equivalent.

Farmer's Drill. A straight-fluted form of drill. See under Drills the paragraph on Straight-fluted Drills.

Fathom. A length measure; 1 fathom = 2 yards = 6 feet = 1.8288 meters.

Fatigue Stresses. So-called "fatigue ruptures" occur in parts that are subjected to continually repeated shocks or stresses of small magnitude. Machine parts that are subjected to continual stresses in varying directions, or to repeated shocks, even if of comparatively small magnitude, may fail ultimately if designed, from a mere knowledge of the behavior of the material under a steady stress, such as is imposed upon it by ordinary tensile stress testing machines. Examinations of numerous cases of machine parts, broken under actual working conditions, indicate that at least 80 per cent of these ruptures are caused by fatigue stresses. Most fatigue ruptures are caused by bending stresses, and frequently by a revolving bending stress. Hence, to test materials for this class of stress, the tests should be made to stress the material in a manner similar to that in which it will be stressed under actual working conditions.

Fatigue Testing Machine. One make of fatigue testing machine designed to record the number of alternations of stress that may be applied to a steel specimen before destruction is accomplished, consists of a baseplate provided with a housing in which are mounted ball bearings that carry the specimen in a horizontal plane, and another housing with ball bearings and a shaft on which a pulley is mounted to drive the equipment from a motor. There are also two ball bearings which are put on the specimen to carry the weights that apply the load or stress. Hook-bars are attached to the weight bearing housings. All the ball bearings are provided with easily adjustable compensating chucks to fit the specimen, so it is a simple matter to mount the specimen in the machine. A bracket at one end of the machine carries a revolution counter which records the number of revolutions made by

the specimen under test up to the time of failure. The specimen is connected to this counter by means of a flat notched bar which falls out of position when failure occurs and causes the counter to stop. At the same time the broken specimen swings out of contact with the driving shaft.

Faure Plate. This is a type of electrode for lead batteries, also known as "pasted" plate, in which the active material in the form of lead oxides is applied mechanically to a lead body. After this the plate is subjected to an electrochemical forming process which produces lead peroxide in the positive plates and sponge lead in the negative plates.

Feather. See Spline.

Featheredge Files. Files of this type taper in cross-section from the center toward each edge. They are of blunt form, double-cut, bastard, second-cut, or smooth. This shape is seldom called for, as the knife file is generally used instead.

Feed Mechanisms. The term "feed mechanism" or "feeding mechanism" as applied to machine tools or other classes of manufacturing equipment, usually relates to some form of mechanism (1) for feeding either a cutting tool or the work as in turning, planing, drilling or milling, and generally for providing also means of varying the rate of tool or work movement per revolution or stroke; (2) a mechanism for feeding raw material or parts from some source of supply to the working or operating position. A feed mechanism which is designed to control primarily the rate of tool or work-feeding movement usually consists of a train of gearing with provision for changing the ratio between the driving and driven members. Feed mechanisms of the type for feeding stock or parts are made in a great variety of types and designs, depending upon the nature of the work.

Many machines which operate on large numbers of duplicate parts which are separate or in the form of individual pieces are often equipped with a mechanism for automatically transferring the parts from a magazine or other retaining device, to the tools that perform the necessary operations. The magazine used in conjunction with mechanisms of this kind is arranged for holding enough parts to supply the machine for a certain period, and it is equipped with a mechanical device for removing the parts separately from the magazine and placing them in the correct position wherever the operations are to be performed. The magazine may be in the form of a hopper, or the supply of parts to be operated upon by the machine may be held in some other way. The transfer of the parts from the hopper or main source of supply to the operating tools may be through a chute or passageway leading directly to the tools, or it may be necessary to convey the

parts to the tools by an auxiliary transferring mechanism which acts in unison with the magazine feeding attachment. These automatic feeding mechanisms are usually designed especially for handling a certain product, although some types are capable of application to a limited range of work.

Feed Mechanisms, Power Press. See Power Press Feed Mechanisms.

Feed Rate on Machine Tools. The rate of feed as applied to machine tools in general, usually indicates (1) the movement of a tool per work revolution, (2) the movement of a tool per tool revolution, (3) or the movement of the work per tool revolution.

Rate of Feed in Turning: The term "feed" as applied to a lathe indicates the distance that the tool moves during each revolution of the work. There are two ways of expressing the rate of feed. One is to give the actual tool movement per work revolution in thousandths of an inch. For example, the range of feeds may be given as 0.002 to 0.125 inch. This is the usual method. Another way of indicating a feed range is to give the number of cuts per inch or the number of ridges that would be left by a pointed tool after turning a length of one inch. For example, the feed range might be given as 8 to 400. In connection with turning and other lathe operations, the feed is regulated to suit the kind of material, depth of cut, and in some cases the finish desired.

Rate of Feed in Milling: The feed rate of milling indicates the movement of the work per cutter revolution.

Rate of Feed in Drilling: The rate of feed on drilling machines ordinarily indicates the feeding movement of the drill per drill revolution.

Rate of Feed in Planing: On planers, the rate of feed represents the tool movement per cutting stroke. On shapers, which are also machines of the planing type, the rate of feed represents the work movement per cutting stroke.

Rate of Feed on Gear Hobbers: The feed rate of a gear hobbing machine represents the feeding movement of the hob per revolution of the gear being hobbed.

Feed on Grinding Machines: The traversing movement in grinding is equivalent to the feeding movement on other types of machine tools and represents either the axial movement of the work per work revolution or the traversing movement of the wheel per work revolution, depending upon the design of the machine.

Feed-Water, Boiler. See Boiler Feed-water Hardness; Boiler Feed-water Impurities; Boiler Feed-water Oil Test; Boiler Feed-water Purification.

Fellows Stub-Tooth Gears. See Stub-tooth Gears.

Fernico. A metal alloy with a coefficient of expansion that is practically the same as that of glass and which can be fused with glass without setting up stresses either in the glass or in the alloy. The alloy can be machined, forged, punched, drawn, stamped, soldered, copper-brazed, and welded. Used wherever tight joints are required between metal and glass, as in vacuum tubes and other devices in which lead-in wires or conducting parts must pass through gas-tight insulating seals.

Ferrite. If a piece of iron or steel is placed under the microscope, it will be found that the metal is not absolutely homogeneous, but consists of various constituents slightly different in color and forming a surface similar to that of a granite rock. Just as granite shows distinct crystalline grains of different minerals, so iron or steel consists of a mixture of microscopic particles. When having slowly cooled, for example, if consists of an iron carbide, known as *cementite,* and of *ferrite,* which is pure, or nearly pure, metallic iron. Ferrite is a soft and weak constituent with high electric conductivity, and, in many respects, like copper, except in its color. When carbon is present in iron to any great extent, ferrite is transformed into cementite, which latter constituent is harder than glass and nearly as brittle; hence, if one per cent of carbon is present in the iron, 15 per cent of the soft ferrite is replaced by cementite. This is one of the reasons why even a small addition of carbon in steel changes its mechanical properties to so great a degree. See also Steel, Constituents or Structure.

Ferroalloys. This term is applied to an alloy of iron and some other element or elements (carbon excepted) when such an alloy is to be used as a raw material in the manufacture of ferrous metals. Ferroalloys normally contain an amount of carbon equal to or greater than the carbon content of pig iron, but low-carbon ferroalloys are commercially available. The part played by iron in a ferroalloy is a secondary one; it serves simply as a vehicle for carrying the desired alloying elements.

There are many ferroalloys in common use. Some are used because of the specific properties which they impart to steel when they are dissolved in the iron base, or when they combine with carbon wholly or in part to form carbides. Others are used because of their beneficial effects in ridding steel of impurities, or in rendering impurities harmless. A third group is used to counteract harmful oxides or gases in the steel. The elements of this latter group do not remain in the steel to any great extent after solidification, but are merely fluxes or scavengers of undesirable impurities. Some ferroalloys fall into more than one of the above groups. Some ferroalloys are made in the blast furnace, some in the electric furnace, and some are made by the

thermit process. Those commonly made in the blast furnace are spiegeleisen, ferromanganese, ferrosilicon and ferrophosphorus.

Ferromagnetic. See Magnetic Materials.

Ferromanganese. Ferromanganese is an alloy of manganese and iron, containing generally about 80 per cent of manganese, 15 per cent of iron, and 5 per cent of carbon, with small percentages of silicon and other impurities. Iron-manganese alloys, containing more than 30 per cent manganese are called ferromanganese. Manganese is used as a deoxidizer and desulphurizer in the production of nearly all grades of steel. It reduces the amount of oxygen remaining in the molten steel, and by actively combining with sulphur it removes a principal cause of hot brittleness and imparts to the steel better rolling and forging properties. Manganese also serves as an alloying element in steel, assisting in the production of a fine grain structure and enhancing physical strength and ductility. It is used for this purpose in all grades of steel, whether intended for castings, forgings or rolled products. The most commonly used grade of ferromanganese alloys is termed "Standard Ferromanganese," often referred to as "80 per cent Ferromanganese."

Ferrous Alloys. Ferrous alloys differ from non-ferrous alloys in that they contain iron. Steel and cast iron are outstanding examples of ferrous alloys, whereas in the non-ferrous group there are the various brass, bronze, aluminum and other alloys.

Ferrophosphorus. This is an alloy of iron and phosphorus used for the addition of phosphorus to steel. Two grades of this alloy are made, one having approximately 17 to 19 per cent, and the other 23 to 25 per cent phosphorus. The former is usually produced in the blast furnace and either grade may be produced in the electric furnace.

Ferrosilicon. This is an alloy of iron and silicon used for adding silicon in the manufacture of open-hearth steel. In the basic open-hearth process it is used as a deoxidizer and scavenger prior to the use of more expensive alloys. It is also used to prevent oxidation while holding the bath of steel for chemical determinations. High-silicon ferroalloys find use in the manufacture of steel sheets or strips in which high magnetic permeability and electrical resistance combined with low-hysteresis are essential. Ferrosilicon is also used extensively in the manufacture of steels in which silicon as an alloying element is desirable. Ferrosilicon is produced in many different grades dependent upon the purpose for whch it is intended. The low silicon grades which start at 10 per cent silicon and ordinarily do not exceed 17 per cent, are generally blast furnace products and are called *silvery pig iron.*

Fiber. This is the general name used for a number of structural components of animal and vegetable tissue utilized in the industries. According to the source of the raw material, there are a number of classes of fiber, such as wood fiber, horn fiber, asbestos fiber, etc. Fiber is used for gearing, for friction wheels, as an electric insulating material, and for various other purposes.

Fiber Bending and Forming. Fiber should always be bent parallel to the grain (the long way of the sheet), because it is difficult to bend fiber across the grain without breaking it. The general practice is to soften the material (more or less) by immersing it in hot or cold water until sufficiently tempered, and then drying it in heated forms under enough pressure to keep the shape desired. The fiber should be left in the heated forms long enough so that it will retain the desired shape after cooling. However, heated forms are not always necessary. If the material can be steamed, instead of immersed, it will require less time to set. Angles can be bent in bending brakes fitted with electric, gas, or steam heat. Special pieces can be formed on a hot plate in cast-iron forms, under pressure of a hand-operated spring plunger. In making up the top and bottom forms, some allowance should be made for the fact that fiber swells slightly when it is soaked or steamed. Tubes can be bent by softening in hot water, filling with sand, and clamping in wooden or metal forms, after which it is necessary to dry them at about 150 degrees F.

Fiber Glass. Glass fibers are produced in two distinct types—staple length and continuous. The former are comparatively short fibers, from 8 to 15 inches long, and approximately 0.00025 inch in diameter. Fabrics made from these short fibers resemble cotton or woolen yarns. The continuous fibers, as their name implies, are produced in continuous lengths, limited only by the size of the spools on which they are wound. Their diameter averages about 0.0002 inch.

In the manufacturing process, the fine glass strands are placed on textile spinning machines, where the yarn is spun in the same manner as cotton or wool yarn. The yarn for fabrics produced from continuous fibers resembles silk or rayon in appearance. Glass fibers of diameters such as are used in making textiles for electrical insulation have extremely high breaking strength. The strength of individual fibers 0.0002 inch in diameter has been shown to exceed 1,000,000 pounds per square inch. No other textile fiber approaches this strength. Tests also show that woven glass fabric is stronger than other textile fabrics. These fibers are made from ¾-inch glass marbles. One marble makes a fiber 0.0002 inch in diameter 98 miles long. One pound of marbles makes 5000 miles of fiber.

One of the interesting applications of "Fiberglas" is for the

insulation of electric motors. A "Fiberglas"-insulated motor is much smaller than one having cotton insulation. In fact, the space occupied by a "Fiberglas" motor is about 45 per cent less than that required for a standard motor. This space saving is an important factor in connection with drives requiring a compact design.

Fiber Punching. Fiber can be easily blanked, pierced, and shaved on ordinary punch presses. For blanking and piercing thin material, the punch should be a neat fit in the die, while for stock ¼ inch thick, a difference of about 0.008 inch will give the best results. When a rough edge is not objectionable, fiber can be blanked out up to ¼ inch thick. When heavier stock is blanked, it is likely to "check in" too far and cause considerable wastage, although some material up to 7/16 inch in thickness can be blanked. Smooth edges can be obtained by forcing blanked or sawed fiber blocks through a hollow shaving cutter of the desired shape. The edges of the cutter should have a slant of about 45 degrees. Sharper angles will often give smoother edges, but the cutter will not last as long. A better finish can be had by using a roughing and a finishing cutter. It is generally necessary to allow from 1/16 to ⅛ inch all around for shaving, according to the shape of the pieces. When trouble is encountered by checking of the stock while blanking or shaving, softening the fiber by heating will often overcome the difficulty. Dies and cutters for fiber can be made without any clearance for ½ inch or more below the cutting edge. The bottom of the die may be counterbored within ½ or ¾ inch of the top to facilitate machining. Such a die will not change its size in grinding and will give better results than a die with clearance to the cutting edge. If the cutting edge of a shaving cutter is mouthed out very slightly with a fine oilstone, the stock will bind slightly in passing through, which will tend to polish the edges smoothly.

Field Switches. Field switches are especially designed to open or change the connections of the field of a motor or generator. One type, for example, has an auxiliary contact which places a discharge resistance across the field before the switch is opened. Another type called the *field break-up switch,* when opened, separates a field winding into two or more sections, insulated from one another.

File Cleaning. A piece of copper is fairly good for cleaning files but sheet-fiber is much better. A disk of fiber mounted upon an ordinary emery wheel stand is very effective. When the file to be cleaned is held against this revolving disk or fiber it will be cleaned much quicker and better than would be possible by hand or by the copper method. Fiber ¼ inch thick is best suited for this purpose.

File History. One of the earliest implements for filing, to which reference can be found, appears to have been made from the skins of certain fish, and even today in Great Britain old-fashioned wood carvers use the skins of the dog fish to smooth their work. *Bronze files* were in use when this metal was the general material for tools and implements, and there is evidence in the Bible that different shapes of files were in use about three thousand years ago. Several specimens of ancient bronze files are still in existence. One of these, believed to be about 3500 years old, was dug up in Crete. This file has a rounded back, as well as a flat surface, bearing an astonishing resemblance to the half-round file of today. It is about $3\frac{5}{8}$ inches long, $\frac{3}{8}$ inch wide, and $\frac{1}{4}$ inch thick.

One of the earliest examples of *iron files* was found on the site of the Swiss lake dwellings, and dates from the time when Europe was the home of a race far more ancient than any of which we have any permanent records. This file has coarse teeth running across the blade at right angles to the sides and has a well developed tang, much like that of modern files. Another ancient iron file forms part of the collection of tools left at Thebes in Egypt by Assyrian invaders. This file is believed to date from about the seventh century B. C. Files have been found on the sites of the old Roman camps in England.

Specific references to files were made by Daimachus, a Greek writer in the time of Alexander the Great, about 300 years B. C. This writer enumerates four kinds of steel, describing their uses. From one kind were made files, augers, chisels, and implements for cutting stone. *Steel files* have been used for several centuries, and in an eighteenth century French encyclopedia there are a number of illustrations of files which differ in few respects from the modern tool. Formerly all files were cut by hand, but now practically all files are machine-cut. Although the machine-cutting of files is a comparatively recent development, the idea of machine-cutting is by no means new. Raoul, a Frenchman, cut files by machinery in the eighteenth century, and in 1836 a file-cutting machine patented by Captain John Ericsson was used in England. Machine-cut files are made with as many as 180 teeth to the inch, the cuts being scarcely discernible to the eye.

File Shapes. See name of file, such as Cant-file; Circular File; Flat File; Half-round Files; Rotary Files; Round Files, etc.

Files, Types. The following types conform to the simplified practice recommendation of the National Bureau of Standards.

Band-saw, Blunt: Equilaterally triangular in section. Parallel throughout. Corners rounded. For sharpening saws with rounded gullets.

Band-saw, Taper: Same as band-saw, blunt, but tapered on all sides.

Cabinet: Flat on one side, convex on the other. Width tapered. Edges slightly blunted and cut.

Cant-saw: Section is an isosceles triangle, with an obtuse angle between the equal sides. For filing cross-cut saws having M-shaped teeth.

Cross-cut (Great American): Knife-shaped section; that is, thicker at one edge than at the other. Width uniform. Thick edge rounded. Used to file two-man saws having Great American style teeth.

Double-ender: Has no tang. Reversible. Tapered from center to each end.

Flat: Width and thickness uniform from heel to middle of cut, and tapered from middle of cut to point.

Half-round: One side flat, the other convex. Width and thickness tapered.

Hand: Width uniform, thickness tapered.

Hand-finishing: Section of regular hand files, up-cut at a short angle, and over-cut at a very long angle to produce a very smooth finish.

Hand-saw, Blunt: Equilaterally triangular in section. Edges parallel throughout.

Knife: Of knife-shaped section; that is, thicker at one edge than at the other. Width tapered.

Lead-float: Open single-cut type having teeth at proper angle for use on lead.

Mill: Width and thickness tapered.

Mill Blunt: Sides and faces parallel.

Pillar: Width uniform, thickness tapered. In general, the thickness is greater, relative to the width, than in other types.

Planer-knife: Parallel in width and thickness. One half of each side single cut, the other half double cut.

Round: Round in section and tapered.

Special Cross-cut: Sides and face parallel, same as mill blunt.

Square: Square in section. Tapered on all sides.

Taper: Equilaterally triangular in section. Tapered on all sides.

Three-square: Equilaterally triangular in section. Tapered on all sides.

Warding: Width greatly tapered, thickness very slightly tapered.

Wood: Open double-cut type having teeth at proper angle for use on wood.

File Teeth. A *single-cut* file or "float," as the coarser cuts are sometimes called, has single rows of parallel teeth extending

across the face at an angle of from 65 to 85 degrees with the axis of the file. This angle depends upon the form of the file and the nature of the work it is intended for. A *double-cut* file has two rows of teeth crossing each other. The angle of the first row is, for general work, from 40 to 45 degrees, and the second row, from 70 to 80 degrees. *Rasp* teeth are round on top and disconnected, being formed by raising, with a punch, small portions of stock from the surface of the blank.

Single- and double-cut files are further classified according to the spacing of the teeth. The names commonly used to designate the different grades of cut are "rough," "coarse," "bastard," "second-cut," "smooth," "dead-smooth," or "super-smooth." "Rough" files are usually single-cut, and the "dead-smooth," double-cut. The other grades are made in both double- and single-cuts. Degrees of coarseness are only comparable when files of the same length are considered, the number of teeth per inch of length decreasing as the length or size of the file increases. Some makers use a series of numbers to designate the cut or coarseness instead of names.

File Teeth, Cutting. There are three general methods of cutting the teeth of files: 1. By hand (using a hammer and chisel). 2. By means of special file-cutting machines of the mechanically-operated chisel type. 3. By etching with a mechanically guided tool. While the hand method is comparatively slow and expensive, skillful workmen are able to produce excellent files, although practically all files now used are cut by machines. These machines have been developed so that they not only enable the work to be done efficiently but produce files which are more accurate and effective than those cut by hand.

The *hand method* to be described has been practiced by the hand file-cutters in Sheffield and Lancashire for a century. The large file blanks are ground, and the smaller ones filed to shape, and slightly greased before cutting. The cutter sits before a square stake on which the blank is laid with the tang toward him and the two ends held down by two leather loops which are pressed down by the right foot. Cutting is begun at the point and is done by a very short chisel, the edge of which is slightly blunted to indent rather than cut the steel. To cut opposite faces of a file the face first cut is laid upon a plate of pewter; triangular and round files are laid in corresponding grooves in blocks of lead.

A *file-cutting machine* is designed to strike a series of rapid blows with a suitably formed chisel, for producing tooth grooves of any desired depth in a file blank which is fed automatically past the chisel at such a rate as to give the desired spacing of the teeth. The chisel head or hammer of a file-cutting machine weighs, complete, from 8 to 12 pounds, and ordinarily makes from

2000 to 3000 strokes per minutes, although the number of strokes may vary from 500 to 3500 per minute, the speed of cutting depending upon the weight of the file being cut. The first known record of a file-cutting machine is a design made by Leonardo da Vinci, the well-known Italian genius, about 1500.

Large quantities of files are not cut by means of a mechanically-operated chisel but by a grooving process that is known as *etching*. This process is entirely different from that of cutting by means of a chisel and produces a higher grade of file. When forming the teeth by etching, the file is laid in a holder where it is steadied and guided by the workman's left hand. With his right hand he operates the etching tool, which is attached to a swinging framework. The etching tool is simply swept back and forth across the work at the proper angle and with the proper degree of pressure, the latter being controlled by the foot of the operator which bears down upon a stirrup which hangs from the handle of the etching tool. This pressure must be varied to suit conditions, such as hard spots in the blanks or the necessity of cutting deeper at one point than at another. The shape of the file is what determines whether a blank should be etched or cut with a chisel. A flat surface should not be etched nor is there any need for it. On round surfaces, however, particularly where it is necessary to preserve accurately the outline of the blank, etching is preferable to cutting. A satisfactory machine has been developed for etching the first teeth of a double-cut file.

File Teeth, Resharpening. There are several processes for resharpening files by the use of acid solutions. The acid must not be permitted to attack the files unduly. To prevent this, it is advisable to make a few tests or trials to determine the length of time the files should be immersed in order to obtain the desired results, before proceeding with the work on a quantity basis.

Cleaning Solution: First clean the files by immersing them in a solution of caustic coda and boiling water for a period of from ten to fifteen minutes. This solution is made by dissolving 100 grains of caustic soda in one gallon of water. The same proportions should be used if a larger quantity of the solution is required. Two gallons will ordinarily be sufficient for cleaning 100 files of the sizes generally employed in the shop.

Use of Nitric and Sulphuric Acids: After the cleansing treatment, the files are placed in an acid bath. This bath is made by adding twelve parts of water (by volume) to a solution consisting of one part nitric acid, one part fuming (Nordhausen) sulphuric acid, and one-third part concentrated sulphuric acid. These parts are measured by volume and not by weight. The files, when placed in the acid solution, should not overlap and should be arranged so that the solution will reach all surfaces. It is preferable first

to suspend the files in the tank and then add the acid solution. The files should be allowed to remain in the solution from five to ten minutes, the exact time being determined by experiment.

Sulphuric-acid Process: Experience in sharpening between 2000 and 3000 files in acid solutions indicates that the following method gives good results. The first step is to remove all grease and dirt from the files. This may be done by soaking the files a few hours in gasoline and then brushing them with a wire brush, or by boiling them a few minutes in a 10 or 15 per cent water solution of caustic soda, and then drying and brushing them. It is essential that the files be thoroughly cleaned, as the acid cannot reach the steel through grease or oil. The clean files are placed in an enamel basin, a lead-lined box, or a "Pyrex" glass baking dish. Short pieces of wire or nails are placed between the files to separate them sufficiently to permit the acid to reach all the surfaces that are to be sharpened.

After covering the files with water, sulphuric acid is slowly poured into the tank until a solution that is about 25 per cent acid is obtained. As the acid combines with the water, a considerable amount of heat is generated which causes the acid to act more rapidly. Files having fine teeth may be sharpened in from three to five minutes, while files with coarse teeth generally require from five to twenty minutes. A second batch of files can be treated in the same solution by adding a little sulphuric acid. After two or three batches of files have been treated, however, it is usually necessary either to heat the solution or make a new one.

Nitric and Hydrochloric Acids: Another process consists of immersing the files in a warm aqueous solution of nitric acid and hydrochloric acid, consisting preferably of about equal parts of the acids and of water. This solution should be kept at a constant temperature. After the files have been treated with the acid solution, they should be washed in lime water or some other alkaline solution, and then wiped with oil.

Adding Acid to Water: Caution must be exercised in mixing sulphuric acid and water. Always pour the acid into the water slowly; never pour water on the acid, as an explosion may result, the same as when babbitt is poured into a wet box or mold. In both cases the explosion is caused by the sudden generation of steam. Commercial hydrochloric acid diluted with about 10 per cent water and heated to near the boiling point can be used instead of sulphuric-acid solution. The diluted hydrochloric acid has the advantage of being safer to handle.

As soon as the files are removed from the acid solution, they are washed in running water and dried rapidly by heating. After drying, they may be dipped in gasoline containing about 5 per

cent paraffin or engine oil. The gasoline evaporates, leaving a thin coat of oil on the files.

File Terms. The *length* of a file means the distance from the point to the heel and does not include the tang. The *heel* is that end of the file body adjacent to the handle. A *blunt file* is one having the same sectional shape from the point to the tang. The coarse grades of single-cut files are sometimes called *floats*. *Safe-edge* means that the edge or side is smooth and without teeth, and may be presented to a surface that does not require filing. *Over-cut* is a term used to describe the first series of teeth on a double-cut file. *Up-cut* means the series of teeth superimposed on the over-cut series of a double-cut file. *Re-cut* means the working over of old worn-out files by annealing, grinding out the old teeth, re-cutting, hardening, etc. Re-cutting is seldom practiced at the present time. The term *superfine* (or super) cut is used by Lancashire file-makers to designate the grade of cut known in the United States as "dead-smooth." *Taper* is used to distinguish a file having tapering sides from one that is blunt or straight. A file is tapered when it is thinner at the point than at the middle, and is full-tapered when thinner at the point and the heel than at the middle. Custom has also established the use of the term "taper" as a short name for "three-square" or triangular handsaw files.

File Testing. The quality of files can be tested by a special machine which records the endurance and capacity for removing metal, by producing a curve or diagram on sectioned paper wound about a cylindrical drum connected with the file reciprocating mechanism, so as to make one revolution to 120,000 strokes of the file. On these diagrams, the horizontal distances represent the number of strokes made by the file being tested and the vertical distances, the number of cubic inches of metal removed. Tests show a remarkable difference in the quality of files, some being worn out after removing less than one cubic inch of iron, and cutting at the rate of only one cubic inch per 10,000 strokes; whereas, files of good quality remove 12½ cubic inches and cut at the rate of 5 cubic inches per 10,000 strokes.

It has been estimated that the useful life of a file is, on an average, 25,000 strokes, which is equivalent to two full working days of ten hours each.

Filing Machines. Filing may be done mechanically especially for such work as filing the openings in blanking dies or whenever a power-driven mechanically-guided file is desirable. One type of filing machine is of the reciprocating type. Another filing machine adapted to die and similar work is of the continuous filing type. This machine is designed along the general lines of

a band saw and the files, which are attached to a band or chain, provide a continuous filing or cutting action. As the filing movement is always in the working or cutting direction, there being no reversal, the life of the files is greatly increased. This machine may be equipped with files of whatever cross-sectional shape conforms closest to the outline of the die. The file-holding band may be uncoupled at one point for inserting or removing a die. One advantage of a die-filing machine, as compared with hand filing, is that straight or flat surfaces can be filed without difficulty because the file is mechanically guided and moves in a straight line, whereas, when filing by hand, it is difficult to do the work accurately.

Fillets. Fillets are concave moldings used in patternmaking to fill in the sharp corners formed by surfaces lying in planes at an angle to each other. They are very important in making machinery castings as the strength of the cast piece is greatly increased by their use, and its liability to fracture is greatly lessened. Fillets are either "stuck" or "planted." A stuck fillet is one that is worked from the solid, and a planted fillet is one made separately and applied. Planted fillets, which are the ones commonly used, are made of wood, leather, beeswax, putty, and other plastic materials. Metal fillets have also been used to some extent, but are not very popular, as they are hard to fasten and soon work loose.

Wood fillets are made by the patternmaker with a round sole plane and are used where corner radii of 1 inch and over are required. *Leather fillets* are in general use for filleting of 1-inch radius or less, and may be worked into any corner whether the angle be acute or obtuse. They are usually worked in place with a spherical-ended tool. Owing to their pliability, leather fillets can be used either on straight work or regular and irregular curves. *Beeswax* and other plastic materials are quite commonly used for fillets of small radii.

Filters for Air. The air cleaner most widely used for the extraction of dangerous dusts of small dimensions is the cloth filter, either of the bag or screen type. When well engineered and maintained, filters are capable of collecting 99% or more of dusts as small as 0.5 microns. The optimum velocity through the filter medium depends upon the dust loading of the entering air, the plugging characteristics of the dust, the maximum allowable pressure drop, the frequency of cleaning and other factors. The air volume per square foot of cloth varies from ½ to 6 c.f.m. in commercial filters. A filtration rate of 4 f.p.m. is usually satisfactory for the recovery of precious metal polishing dusts, foundry dusts and pulverized mineral dusts such as cement, feldspar, limestone and similar materials. The filter is inherently a high-

resistance cleaner. Its filtration efficiency depends to a considerable extent on the accumulation of deposited dust. The formation of the dust mat, on the other hand, increases the resistance substantially. The pressure drop is greatest just before the filter is shaken and is lowest immediately after cleaning.

Filters for Boiler Feed Water. River water often contains the discharge from sewers, fine sand, or other fine particles which will readily pass through the finest strainer and also float in still water. In cases of this kind, some form of filter is necessary for boiler feed water. Such filters are usually composed of crushed quartz, coke or charcoal, excelsior, burlap, or other porous material which will pack closely and present a rough surface to which the particles of solid material will readily adhere. There are many forms of filters in use, one of the simplest consists of a wooden tank having three compartments. The main compartment has a perforated bottom which supports a bed of coke. The water enters at one end near the top and passes through the filter into a compartment below. The water then passes into a third compartment at the opposite side of the filter from which the water enters, and from here it is drawn out by a pump. Particles of coke or sand which may be carried through the filter will collect in the bottom of the second chamber. In another form, known as a *pressure filter,* the filtering material is sharp sand, machine-crushed and sifted quartz or the like. In general the feed water enters at the top, passes downward through a comparatively deep filter bed and out through a pipe which is connected with a system of strainers. The filtering material is broken up and cleansed by means of a steel agitator driven by a worm-gear at the top.

Filters for Removing Fine Particles from Coolants and Lubricants. Filters are used for re-conditioning the cutting oils or coolants on certain types of machine tools and they may also be applied to lubricating oil systems. The value of some sort of filtration of grinding coolant to remove particles of wheel grit and metal chips has been recognized in connection with certain grinding operations for many years. The need for grit-free coolant is most apparent when fine-grit wheels are used to produce a high finish on work such as hardened steel rolls for cold-rolling metal. The reason is that fine-grit wheels are dense and particles of abrasive carried in the coolant between the wheel and the work cannot embed themselves in the pores of the wheel face; consequently, they are likely to scratch the work.

Mechanical Filters: Mechanical filters have been developed which can be installed in the coolant supply line of most cylindrical grinders. Their use is frequently recommended by grinding machine manufacturers, and, in many cases, machines are sold equipped with filters. Their application seems to be principally

for the improvement of finish, although other advantages have been proved that should make their use much more general. Not only are scratches reduced or prevented and a better finish obtained, but the grinding wheel faces are kept clean, so that they cut better and require less dressing. This results in a reduction of abrasive costs through longer wheel life and higher production, because of the better wheel action and less time lost in wheel dressing.

Magnetic Filter: One type of filter for removing iron and steel particles from coolants or lubricating oils, operates magnetically. It is claimed that the Frantz "FerroFilter" will remove particles as fine as 1/25,000 inch from suspension in liquids. It is applicable to machine tool cutting oil systems and to the lubricating systems of Diesel engines, aircraft engine test and run-in stands, reduction gears, etc. The liquid material to be cleaned is passed through a stack of magnetized screens. These screens are enclosed in a cylindrical casing. The screens, although offering comparatively little resistance to the flow of the liquid, present up to 8000 feet of strongly magnetized edges which catch and hold the particles of iron until the machine is shut down. The filter is then demagnetized and flushed. The filter may be operated by direct current at 110 to 120 volts, but portable tube-type rectifiers are available which will supply the required current from a sixty-cycle, alternating-current lamp socket.

Finished Surface Inspection. Very slight cracks in ground surfaces that cannot be seen even with a microscope can be discovered by magnetizing the part and immersing it in a solution of kerosene oil having very fine iron dust suspended in it. A magnetic field immediately surrounds the crack and the fine iron particles adhere in a peculiar shape to the hardened surface where the surface crack appears. This method of inspection has to do only with the quality of the surface, but not directly with the actual degree of finish.

Finishing Steels. Tool steels of this class are especially adapted to finishing cuts as in turning long shafts. Finishing steels are very similar to carbon steels in that they have a very high cold hardness. In addition, they contain enough alloying elements to enable them to retain their hardness somewhat better at the higher speeds than is possible with the straight carbon steels.

Low-Cobalt Finishing Tools: As a general rule, finishing tools should be tough and hard. Low-cobalt high-speed steel answers this requirement very satisfactorily. The advantages of this steel over the high-tungsten high-speed steel are due to the high temperature it can stand and to its ability to maintain a good cutting edge under long finishing cuts. This material has been found

better adapted for screw machine work than the high-tungsten or even the high-cobalt high-speed steel.

Finishing Steels for Drills: Drill steels generally known as "finishing steels" are a low-tungsten type of tool steel. This is an intermediate type of steel sold as either carbon, super-carbon, or alloy tool steel. The carbon content usually ranges from about 1 to 1.25; the tungsten, from 0.2 to 2.7; and chromium, from 0.5 to 1.2. Some of these steels also have 0.2 or 0.3 per cent of vanadium. Drills made from these finishing steels are used to advantage in place of plain carbon steel tools when increased cutting speed and longer life are required. They cannot, however, be compared with high-speed steel drills.

Finish Marks or Symbols. The finish marks used on drawings may show merely what surfaces are to be finished or they may also indicate with varying degrees of exactness, the quality of the finish. The letter *f* has been used extensively to show that some kind of finish is required. It is common practice to so place this letter that its cross-line intersects the line on the drawing representing the surface to be finished. The practice of some concerns is to use the capital letter *F* with the foot of the letter resting on the line indicating the surface to be finished. The quality of a finished surface may be indicated definitely and precisely by a number representing a micro-inch reading and also by a graphic record on a chart. See Finish or Surface Quality.

American Standard Finish Marks: A surface to be machined or "finished" from unfinished material such as a casting or a forging should be marked with a 60-degree "V," the bottom of the "V" touching the line representing the surface to be machined or finished. A code figure or letter should then be placed in the opening of the "V" to indicate the quality of the finish desired. The meaning of these code figures or letters should then be indicated by notes at the bottom or side of the drawings.

Finish or Surface Quality. All metal surfaces which have been finished by turning, grinding, honing, or other means, consist of more or less minute irregularities. If, from a central reference line, the heights and depths of these irregularities are measured at equally spaced intervals, and if the sum of such measurements is divided by the number of points at which measurements are made, the resulting average might be used in comparing the roughness of this surface with that of another having an average value obtained in a similar manner. If these measurements are in micro-inches (1 micro-inch equals 0.000001 inch), and if each measurement is squared, then averaged as explained, the square root of this average yields a figure indicative of surface roughness which is much more convenient to use in practical work. Assume that the quantities a, b, c, etc., equal the various

profile measurements in micro-inches and m equals number of points measured; then surface roughness may be indicated by the following *root mean square* (rms) formula:

$$\text{rms value} = \sqrt{\frac{1}{m}(a^2 + b^2 + c^2 \ldots)}$$

The irregularities on any surface vary in size and the root mean square average value represented by the preceding formula gives the larger profile values greater weight than the smaller ones, which is desirable in a surface profile roughness number. This root mean square value is being utilized, especially in some of the larger plants, to indicate surface roughness. This has been made possible by the development of an instrument for determining readily in the shop or inspecting department the equivalent of this rms value, or, in other words, a practical and precise roughness value.

Instrument for Obtaining Micro-inch Reading: The magnitude of surface irregularities serve as a practical basis for roughness ratings. Individual peaks and valleys of roughness are seldom of importance; but an *average value* over ⅛ inch or more of surface profile is a practical rating of roughness. Such an average includes several hundred irregularities on most surfaces. An instrument known as the *Profilometer* measures a running average of the heights of irregularities as the motions of a tracer point are transformed to electrical voltages, amplified and measured. The automatic averaging feature consists of an electrical meter calibrated in micro-inches. This micro-inch reading is the root mean square average (rms) represented basically by the preceding formula. The instrument may be applied to flat, cylindrical, or curved surfaces, and the tracer can be moved manually or mechanically. For very smooth surfaces, mechanical tracing is recommended. To illustrate the practical application, if a drawing specifies a surface roughness value of, say, 30 for one surface and possibly 100 for another surface on the same part, the Profilometer shows whether these two surfaces on the finished part conform to the drawing specifications.

Graphic Record of Surface Quality: The Brush "Surface Analyzer" produces on a chart a graphic record of the quality or "topography" of a finished surface. The instrument records the amplitude as well as the number of irregularities within a certain area, and at the same time indicates whether they are above or below the normal bearing surface. Absolute measurements are shown without resorting to conversion formulas, and values in fractions of micro-inches can be easily determined. A finely polished sapphire stylus explores or passes over the surface and the irregularities displace the stylus, which, in turn, actuates a piezo

crystal element. The minute voltages generated by the crystal are then magnified by an amplifier which provides sufficient voltage for operating a direct-inking oscillograph. The oscillograph includes a piezo electric crystal element which converts this voltage into a recording pen movement. These deflections, recorded in ink on a moving paper chart, are directly proportional to the movements of the stylus on the specimen surface, but are magnified as much as one hundred thousand times. The apparatus may be set up in the shop or laboratory and placed in operation by simply plugging into 110- to 220-volt, 60-cycle, alternating current.

Microscopic Comparison with Standard: An instrument known as the *Comparoscope* is a portable microscope designed for comparing the finish on machine parts, etc., with a standard having the quality of finish desired. This comparative microscope is self-illuminating, self-focussing and self-aligning. It can be used on round or flat specimens of any dimensions. It shows through the single eye-piece a clear magnified comparison of the work piece and standard, side by side. The "Comparoscope" is particularly adapted for testing finishes on crankshafts, camshafts, wrist-pins, pistons, valves, tappets, etc. It can also be used for examining and comparing the sizes of abrasive grains and their structure and spacing in grinding wheels and abrasive paper and abrasive cloth. The surface finishes on gages and the fractures caused by hardening can also be examined.

Fin of Drop-Forging. On a drop-forging the fin is the excess metal that is forced out of the die impression into the space between the upper and lower die sections. See Flash of Drop-forging Die.

Fire and Explosion Hazards. Conditions which may cause fire or explosion present hazards which must be considered when installing machinery and equipment, particularly of an electrical nature. The kinds of hazards involved have been grouped into four classes by the National Board of Fire Underwriters, according to the degree of danger involved. Many types of electrical equipment, such as motors and controls, are designed to meet the safety requirements called for by one or more classes of hazard.

Class I locations are those in which inflammable volatile liquids, highly inflammable gases, mixtures, or other highly inflammable substances are manufactured, used, handled, or stored in other than their original containers. There are four groups in this class:

Group A: Atmospheres containing acetylene.

Group B: Atmospheres containing hydrogen or gases or vapors of equivalent hazard, such as manufactured gas.

Group C: Atmospheres containing ethyl ether vapor.

Group D: Atmospheres containing gasoline, petrol
alcohols, acetone, lacquer solvent vapors, and natural _

Groups *A* and *B* present the most severe hazards and there has been considerable difficulty in attempting to standardize electrical equipment to meet them. Group *C* hazards are less severe, and there is a wide range of motors and controls constructed to withstand an internal explosion of the gases or vapors covered by Group *D* without causing such harm as would interfere with their successful operation.

Class II locations are those in which combustible dust is, or may be, held in suspension in the air in sufficient quantities to produce explosive mixtures or in locations where it is impracticable to prevent such combustible dust from collecting on motors, lamps, or other electrical devices that are liable to be overheated because normal radiation is prevented. There are three groups in this class:

Group E: Atmospheres containing metal dust.

Group F: Atmospheres containing carbon black, coal, or coke dust.

Group G: Atmospheres containing grain dust.

Protection against these hazards is afforded by the use of dust-tight enclosures which have accurately machined joints.

Class III locations are those in which easily ignitable fibers of materials producing combustibles are handled, manufactured, or used.

Class IV locations are those in which materials covered in Class III are stored. Protection against these hazards is afforded by the use of enclosing cases which will not allow the escape of any sparking and which will not become overheated when in use.

Firebrick Properties. Brick intended for use in furnaces, flues, and cupolas, where the brickwork is subjected to very high temperatures, is generally known as "firebrick." There are several classes of firebrick, such as fireclay brick, silica brick, bauxite brick, chrome brick, and magnesia brick. Ordinary firebricks are made from fireclay; that is, clays which will stand a high temperature without fusion, excessive shrinkage, or warping. There is no fixed standard of refractoriness for fireclay, but, as a general rule, no clay is classed as a fireclay that fuses below 2900 degrees F. Fireclays vary in composition, but they all contain high percentages of alumina and silica, and only small percentages of such constituents as oxide of iron, magnesia, lime, soda, and potash. A great number of different kinds of firebrick are manufactured to meet the various conditions to which firebricks are subjected. Different classes of bricks are required to withstand different temperatures, as well as the corrosive action of gases, the chemical action of furnace charges, etc. The most common

firebrick will melt at a temperature ranging from 2830 to 3140 degrees F.; bauxite brick, from 2950 to 3245 degrees F.; silica brick, from 3090 to 3100 degrees F.; chromite brick, at 3720 degrees F.; and magnesia brick, at 4950 degrees F.

Fire Cracks. In brass and other alloys, so-called fire cracks are defects due to molecular changes produced by mechanical deformation, which appear during the annealing process. German silver is particularly liable to this defect.

Firecrete, Light-Weight. A light-weight material from which any refractory shape can be obtained quickly by simply mixing it with water and casting it in a form. After being in the form twenty-four hours, the shape is ready to be placed in service. Sixty-five pounds of material are required for each cubic foot of finished construction. Suitable where difficult brick construction is encountered, for lining furnace doors, and for making small monolithic linings. Can be subjected to working temperatures up to 2200 degrees F. Especially advantageous in the case of intermittently operated furnaces, because of its exceptionally low heat storage capacity.

Fire Hose Couplings. See Hose Couplings.

Fire Point of Oil. The fire point or fire test of an oil is the temperature at which the oil will catch fire and continue to burn. The fire point and the flash point are two important properties in oil, particularly when the oil is used under conditions where it may be exposed to high degrees of temperature, as, for example, in hardening rooms or electric transformers. To make a flash point of fire test, proceed as follows: Place a quantity of oil in an open vessel. Heat it slowly and uniformly and note the temperature by a thermometer immersed in the oil. From time to time, let a small flame impinge upon the surface of the oil; the lowest temperature at which a slight explosion or flash takes place is the *flash point*. Continue this test until the oil will be set afire by the explosion or flash. The temperature when the oil will ignite and burn continuously should be noted on the thermometer. This temperature is the fire point. See Flash Point of Oil.

Fitchburg Plan. This is a system of apprenticeship education in which an arrangement is made between the public high schools and manufacturers, according to which the apprentices spend alternate weeks in the shop and in the school. It is known as the "Fitchburg plan of apprenticeship education" because it was first applied in Fitchburg, Mass. This plan is also called "cooperative apprenticeship."

Fits, Machine. See Driving Fits; Forced Fits; Shrinkage Fits, and Expansion Fits.

Fittings. The term "fittings" as applied to pipe work, includes the various parts used in pipe lines for connecting different pipes, viz., ells or elbows, tees, and crosses, as well as pipe flanges. They are made from cast iron, wrought iron, malleable iron, or composition metal. See Pipe Fittings.

Fixtures. Fixtures may be defined as special devices, used in the manufacture of duplicate parts of machines, or manufactured devices in general, intended to make possible interchangeable work at a reduced cost, as compared with the cost of producing each part individually. The piece of work to be machined is held and properly located in the fixture, the fixture, in turn, being held on the table of the machine on which the operation is to be performed. The terms "jig" and "fixture" are frequently used interchangeably, but, as a general rule, a jig is a tool which, while it holds the work, at the same time also contains guides for the respective tools to be used (for example, a *drill jig*), while a fixture only holds the work while the cutting tools are performing the operation upon the piece, without containing any special arrangements for guiding the tools. The fixture, therefore, must itself be securely held or fixed to the machine on which the operation is performed; hence, the name. Fixtures are mainly used on milling machines, planers, boring mills, and lathes.

Fixture Thread. See Electric Fixture Thread; also Pipe Thread for Fixtures.

Flame Cutting. See Oxy-acetylene Method of Cutting Steel and Iron.

Flame-Descaling. This is a process for removing scale from blooms, billets, slabs, forgings and steel castings by means of specially designed oxy-acetylene heating heads. The process is based on the principle that when high-temperature heating is applied to the scale or oxide skin on a piece of cold metal, the scale expands and breaks away from the base metal, due to the different rates of expansion of the scale and the steel.

Flame-Hardening. Wherever there is the problem of excessive wear due to scraping or cutting action, seizing, or galling, the application either of flame-hardening or hard-surfacing methods may offer an effective solution. In flame-hardening, the oxy-acetylene flame serves only as a heating medium, no change taking place in the chemical composition of the material being hardened. The process differs fundamentally in this respect from casehardening or nitriding. The steel is simply heated with the oxy-acetylene flame to a temperature at which subsequent quenching, usually with water or air, will increase the surface hardness.

Advantages of Flame-Hardening: Flame-hardening advantages include: (1) No change of chemical composition in the hardened

surface. (2) Easy application to limited areas. (3) Possibility of increased hardness, due to the rapid quenching action possible because of the large volume of cold metal beneath the heated surface. (4) Low stresses between the hard surface and the relatively ductile core; this prevents spalling or "shelling out." (5) Feasibility of application to sections as thin as ¼ inch or even thinner, with proper technique. (6) Scale-free surfaces, due to rapidity of treatment.

Heating Methods: The heating operations of flame-hardening may be classified as stationary, progressive, and spinning. In the stationary procedure, sometimes called "spot-hardening," both torch and work are motionless during the operation. With the progressive method, the flame and work are moved relative to each other, and the metal is quenched immediately after it is brought up to temperature. Thus, in flame-hardening a plane surface, the lighted oxy-acetylene torch is directed along the surface at the maximum speed that will permit heating the surface zone above the critical point of the steel, while immediately behind the flame is a stream or spray of water which progressively quenches the heated surface. The speed is determined by operating variables, such as flame intensity, type of steel under treatment, and temperature desired. The usual speeds are from 6 to 8 inches per minute, although the range may extend from 4 to 10 inches per minute.

In the spinning method, principally applied to round parts, the torch is stationary and the work is rotated before the flame. When the entire area has reached the hardening temperature, the quench is applied, with the work still rotating. The time for hardening by this method varies from a few seconds to two or three minutes.

Quenching: For quenching, many devices can be used, ranging from a small stream of water from a round nozzle to a carefully designed spray nozzle. Spinning operations are better controlled by quenching with a large volume of water under low head, which simulates total immersion. Certain steels, too sensitive to be quenched with water, may be treated with a soap-water solution or a soluble cutting oil in water.

As a rule, flame-hardening operations should be followed immediately by a low-temperature draw to relieve quenching stresses; this can be conveniently done in an oil bath or oven. Although generally recommended, the drawing operation is not always necessary, since by carefully controlling the quantity and application of the quenching medium or by delaying its application, the operation becomes "self-drawing."

Applications: Owing to the fact that the flame-hardening is adaptable to complicated parts with less danger of distortion or

other faults than other heat-treating methods, it finds important use in the treatment of the teeth of large gears, rail ends, pump liners, crane wheels, tractor shoes, sheave wheels, machine ways, valves, crankshafts and camshafts, and many other parts.

Steels Suitable for Flame-Hardening: In selecting a suitable steel for flame-hardening, it may be said that plain carbon steels can be hardened satisfactorily by this process, provided the carbon content is more than 0.40 per cent. The upper limit of carbon is dependent upon the method of hardening used, but steels having a carbon content up to 0.70 per cent or even higher, depending upon the sections, can be successfully flame-hardened. Alloy steels of a wide range of compositions can be satisfactorily treated by this process, but in general, because of economic factors, its application is restricted to the low or medium alloy types, that is, those in which the percentage of the principal added elements is small.

Steel Forgings for Gears: While many types of steel forgings can be successfully flame-hardened, S A E 4640 and S A E 6145 are recommended. These steels are usually readily obtainable, comparatively inexpensive, and give uniformly dependable results. A lower-priced steel, S A E X1340, is used especially for some machine tool gears where the tooth loads do not require the maximum possible surface hardness and the sections are light enough to harden and draw to the required core hardness. In specifying S A E X1340, the usual practice is to require that "a 1-inch round section must harden in oil to a minimum hardness of 42 Rockwell C."

Preliminary Heat-Treatment of Steel Forgings: Since flame-hardening has no effect on the core, it is essential that the core strength be obtained before the blanks are machined. The following preliminary heat-treatment is specified: Normalize, reheat, quench, and draw to the required hardness. The required degree of core hardness will vary from 235 to 302 Brinell, according to the stresses to which the gears are subjected in service. In a few cases, where the tooth loads are extremely high, a core hardness of from 302 to 341 Brinell is specified.

The preferred practice is to purchase the forgings in the untreated state, rough-machine them, rough-cut the teeth, heat-treat them to the desired core condition, and then finish-machine them, finish-cut the teeth, and flame-harden them. The maximum resistance to shock is generally obtained by reheating after quenching to about 1200 degrees F., from which temperature, in the case of carbon steel at least, the metal may be again quenched or slowly cooled. This treatment results in a very fine grain.

Preliminary Heat-Treatment of Steel Castings: For flame-hardened gears, steel castings containing from 1.00 to 1.50 per

cent manganese and 0.35 per cent carbon are recommended. It is well to include in the specification the statement: "Analysis should be suitable for flame-hardening." The exact analysis may then be left to the steel foundry. The castings must be given a preliminary heat-treatment, preferably by the foundry, in order to obtain the required core structure.

Flame-Hardening Machines: Special machines have been developed for flame-hardening the teeth of gears. While flame-hardening of gear teeth has been done by hand, this method is dependent upon human judgment, and there is danger of overheating, cracking, and non-uniform hardness. Gas-cutting equipment of the standardized types has a limited application in gear hardening, but special machines are preferable. A modern type heats and quenches both sides of a gear tooth simultaneously. Previously only one side of a tooth was hardened at one time. This caused unequal stresses in the tooth, resulting in distortion. Furthermore, the temper on the first side was often slightly drawn when the second side was heated for hardening. These difficulties are eliminated when both sides of the teeth are hardened at once.

Flame, Neutral. See Neutral Flame.

Flamenol. Synthetic insulating compound similar to rubber in its characteristics, but does not contain rubber and is not combustible; can be compounded, filled, calendered, and extruded in much the same manner as rubber. Used as an insulation on cable because of being highly resistant to moisture, acids, alkalies, and oils; is available in a variety of colors.

Flame-Softening. Most steels can be flame-cut without detrimental effect, but there are some harder grades of steel, particularly the low-alloy high-strength types, which tend to harden along the cut edge as a result of the cutting operation. A process, known as flame-softening, provides a simple and economical means for restoring the steel to its soft condition. Multi-flame heating heads, which usually operate simultaneously with the cutting, heat the body of the metal after cutting, so that the cut edge is annealed or tempered.

There are three methods of applying flame-softening. The first is applicable to plate thicknesses up to and including 1½ inches, in which case a single multi-flame heating head, either directly before or after the cutting tip, is directed toward the top of the cut edge. The second treatment is applicable to thicknesses from 1½ to 4 inches, and is similar to the first one, with the exception that an additional multi-flame head is directed at the bottom of the cut edge. The third method is applicable to thicknesses above 4 inches, the multi-flame head being directed against the face

of the cut edge following the cutting operation, but before the steel is cooled to room temperature.

The flame-softening process has been successfully applied to cut edges of gusset plates and web plates for buildings and bridges, to structural plates, railroad cars, the cutting of high-strength steel products in steel warehouses, and the finish-treating of carbon steels of 0.40 per cent or more in steel mills.

Flange Steel. So-called "flange steel," which is generally used for the heads of steam boilers, is an especially tough and ductile quality of open-hearth steel. The A. S. M. E. boiler code specifications for flange steel are as follows: Manganese, 0.30 to 0.60 per cent; phosphorus, acid, not over 0.05 per cent; phosphorus, basic, not over 0.04 per cent; sulphur, not over 0.05 per cent. An analysis is to be made by the manufacturer from a test ingot taken during the pouring of each melt, and a copy given to the purchaser or his representative.

Flash-Ex. A metal coating eliminating the necessity of grinding or chipping weld spatter from the metal surrounding a weld. The white and pigmented coating prevents the adhesion of spatter to the welded parts, dies, or welding-holder jaws. After the welding operation, any spatter is merely brushed off. This metal coating is used in resistance welding to prevent the dies and welding-holder jaws from becoming jammed due to spatter.

Flash Point of Oil. In specifying oil for various purposes, a flash point and a fire point are often specified. If oil is heated slowly, it will vaporize, forming an inflammable and explosive mixture with the air over the surface of the oil, and at a certain temperature it will be found that this vapor will flash up, if ignited, but the main body of the oil will not ignite. On further heating, a temperature is reached when the production of vapor is rapid enough to maintain a continuous flame, and then the body of the oil catches fire and burns. The *flash point* is the lowest temperature at which the vapor will flash up without setting the oil on fire; the *fire point* is the lowest temperature at which the oil will burn. In some oils these points come so near together that it is impossible to distinguish between them, while in other oils they may be 20 degrees or more apart. The flash point is not an indication of the value of an oil for any particular purpose. It is simply an indication of the temperature at which the oil gives off vapors in such proportion that they form an inflammable mixture with the air. The flash points of mineral lubricating oils vary, with few exceptions, from 300 to 600 degrees F. The flash point can be considerably exceeded if the oil is protected by steam.

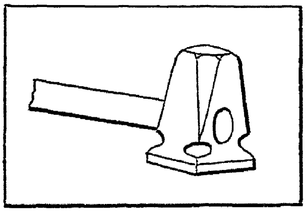
Flasks for Molding. Flasks or molding boxes confine the sand used in making all molds that are not formed in the floor. They

may be of wood or iron and in shapes or sizes to suit the work. The iron flasks are superior, as there is less likelihood of straining the mold in handling it, and the smaller sizes are made interchangeable, the pins and holes of a given size flask being the same. *Snap flasks* are hinged at one corner or side and are held together with a snap fastened at the opposite corner. This type of flask confines the sand while the mold is being made, but may be removed as soon as the mold is finished, so that it can be used again before the mold is poured. Snap flasks are used for light work and are usually square, rectangular, or round.

Flat File. A flat file is parallel in both longitudinal sections, from the heel to the middle, and tapered in both sections from the middle to the point, the thickness of the point being about two-thirds and the width about one-half that of the stock from which the file is made. The flat file is one of the most common files in use and is not confined to any specific class of work, but is employed for a great variety of purposes. Ordinarily, the teeth are double-cut, and either bastard, second-cut, or smooth. A single-cut flat file is preferred for some classes of work.

Flat Key. A flat key differs from a saddle key in that it bears against a flat surface on the shaft. The key is not sunk into the shaft but it gives it a fairly good grip. This type is not adapted to heavy work, however, owing to the excessive strains to which the hub is subjected, as the shaft tends to turn.

Flattening Test. This term as applied to tubing refers to a method of testing a section of tubing by flattening it until the inside walls are parallel and separated by a given distance—usually equal to three times the wall thickness for seamless tubes and five times the wall thickness for lap-welded tubes. Boiler tubes subjected to this test should show no cracks or flaws. The flattening test applied to *rivets*, consists in flattening a rivet head while hot to a diameter equal to $2\frac{1}{2}$ times the diameter of the shank or body of the rivet. Good rivet steel must not crack at the edges of the flattened head.



Blacksmith's Flatter

Flatters. The tools used by blacksmiths for finishing the flat surfaces of forgings are called *flatters* and *sets*. Flatters are generally made from $2\frac{1}{4}$ to $2\frac{3}{4}$ inches square on the face, which should be slightly crowning in the center and the edges well rounded off to prevent their leaving sharp marks upon the work. Sets are of various shapes and sizes, but all are modeled more or less on the same principle as flatters and are used for similar work. It is of advantage to use a flatter with its edges well

rounded for fillets, and one with sharp square edges to finish corners which must be sharp.

Flat Tongs. This is a type of tongs used by blacksmiths. These tongs usually have a small longitudinal V-shaped depression the full length of the flat jaws, so that they can be used to hold round stock or square stock cornerwise.

Flat Turret Lathe. The flat turret lathe is so named because the turret is a flat circular plate mounted on a low carriage to secure direct and rigid support for the tools, from the lathe bed. The tools, instead of being held by shanks inserted in holes in the turret, are clamped firmly onto the low circular turret plate so that they do not overhang, but have an unyielding support directly below the cutting tools. This type of turret lathe was introduced in 1891, and was designed by James Hartness. Lathes of the flat-turret class are sometimes referred to as *turntable lathes.*

Flemish Finish on Brass. The so-called Flemish finish can be given to brass with a solution composed of ¼ ounce of sulphuret of potassium; from 1 to 2 ounces of white arsenic; 1 quart of muriatic acid; and 10 gallons of water. The arsenic should be dissolved in a part of the acid by heating, and then mixed with the balance of the acid and water. Two ounces of sulphuret of potassium in a gallon of water may also be used if it is heated to 160 degrees F. One ounce of sulphuric or muriatic acid in a gallon of water darkens the color produced by this last mixture.

Flexible Couplings. Flexible couplings are the most common mechanical means of compensating for unavoidable errors in alignment of shafts and shafting. When correctly applied, they are highly efficient. For joining lengths of shafting without causing loss of power from bearing friction due to misalignment, and for use in direct motor drives for all kinds of machinery, the value of the flexible coupling is now generally recognized. The fact that limeshafting will sag if of considerable length, makes the use of a flexible connection essential. Flexible couplings are not intended to be used for connecting a driven shaft and a driving shaft that are purposely placed in different planes or at an angle (joints for such service are usually called universal joints) but are intended simply to overcome slight unavoidable errors in alignment that develop in service. There is a wide variety of flexible coupling designs; most of them consist essentially of two flanged members or hubs, fastened to the shafts and connected by some yielding arrangement. The question of balance is an important matter in coupling selection or design, as an increasing number of couplings are used in connection with steam turbines, high-speed motors, and many other classes of machinery.

It is not sufficient that the coupling be perfectly balanced when installed, but it must remain in balance after wear has taken place.

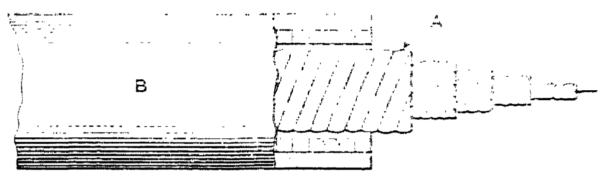
For small drives operating at moderate speeds where low first cost is the only consideration, there are several types of flexible couplings using leather, rubber, or fabric as the flexible element. Special types of couplings have been developed for continuous process work, as on steel rolling mills, where the capacity of the coupling for misalignment is really important. In designing couplings for such service, it is usual to sacrifice a considerable amount of over-all length in order to use what really amounts to two flexible couplings connected by an intermediate shaft, which may vary in length according to the probable maximum amount of off-center misalignment. An all-metal type of flexible coupling is adapted for heavy-duty work, because of the smaller size involved, longer life, and less cost—first and last.

Many drives are started suddenly, and one machine may impose a fluctuating or vibratory load on the other. For such drives it is often desirable to have a cushioning effect between the machines, which is supplied by coil springs or by laminated bundles of springs in the all-metal types. Flexible fabric couplings are noiseless in operation and yield sufficiently to cushion the shock when the clutch is engaged for starting. For this reason, the parts of the transmission are not subjected to such severe stresses as would otherwise be the case. These couplings are said to be durable and strong, but their use is restricted to "straight line" drives or cases where the driving shaft is inclined at an angle of only a few degrees.

Flexible Shafting. Flexible shafting is used for transmitting motion from a source of power usually to some kind of tool or abrasive wheel, and it is so constructed that the driven tool or other device can be moved in any direction, owing to the flexibility of the shaft. Flexible shafting is sometimes used for driving a mechanically-guided tool, such as an auxiliary grinding wheel, which is held in the tool-post of a lathe or planer, but, in most applications of flexible shafting for the transmission of power, the object is to secure a free or universal movement of the driven member. For instance, a common type of portable grinding outfit consists of a motor which is mounted on a truck and drives a grinding wheel by means of a flexible shaft; as the wheel is held and guided by hand, it can be presented to any surface very readily. These flexible-shaft grinders are used for grinding castings or for cleaning castings by replacing the grinding wheel with a wire scratch brush. Flexible shafting is also extensively used for such work as the grinding of dies, driving small polishing wheels, driving drills of the portable type, rotating dental tools, and certain

classes of surgical instruments, and for a great variety of other purposes, requiring a flexible transmission of power.

Flexible shafting consists of an inner core and an outer casing or covering. The core revolves within the casing and transmits motion from the source of power to the driven member. One type of core is composed of several layers of steel wire which are coiled or wound closely upon each other. (See Illustration.) Every alternate layer from the small one in the center to the outer layer is wound in an opposite direction. The cores of some flexible shafts are composed of links which are so formed and joined together that the required amount of flexibility is obtained.



Sectional View of Wire-wound Flexible Shaft

Floating Core. A core in a mold for making a casting is termed a floating core when it is not firmly supported and is lifted from its position by the molten metal as it flows into the mold. Floating cores are often the cause of unsound castings. The buoyant effect of the molten iron on a core is equal to about three times the weight of the core, if the core is solid, and very much more than that if it is hollow.

Floating Foundations. See under Foundations for Machinery.

Floating Levers. See Differential or Floating Levers.

Floating Tool-Holders. A tool is said to "float" when it is not held rigidly but is free to move within certain limits. The floating or free movement may be in one direction only or in any direction. Many reamer-die- and tap-holders are of the floating type as they allow the die or tap to move in the direction of its axis, so that it is free to follow its own lead in case the forward movement is retarded by the backward pull or drag of the turret or tool-slide to which it may be attached. When a tool-holder is arranged to allow a die, tap, reamer, or other tool to move laterally or possibly in any direction, this is to permit the tool to align itself in case a hole is slightly off center. When the work to be operated upon is placed in a chuck either by hand or automatically

from a magazine, a lateral or universal floating movement for the tools is especially desirable because of the difficulty of chucking parts in perfect alignment. Some tool-holders which are supposed to have a free floating movement to compensate for errors of alignment do not have this free movement when the tool is at work, because then there is considerable frictional resistance between the driving lugs or surfaces of the tool-holder.

Flooded Lubrication. See under Lubricating Systems.

Flow Meter. The electrically operated flow meter provides means for accurately measuring the total flow of steam, water, air, gas, oil, etc., through pipes. Due to the electrical principle of operation, the indicating, curve-drawing and integrating instruments can be located any distance away from the pipe where the flow is being metered.

Fluid-Compressed Steel. Steel which has been subjected to compression before the ingots were entirely solidified, in order to secure a perfectly solid and homogeneous mass, is known as fluid-compressed.

Fluid Couplings. See Couplings of Fluid Type.

Fluid Power Transmission. The term "fluid power" has been applied to various forms of fluid or hydraulic transmissions on machines requiring either a straight-line or a rotary drive. In general, the transmission system includes some form of pump to force oil into a cylinder for straight-line movements or into a fluid power motor for rotary motion, and, in addition, suitable controls as for varying the speed or to meet other operating requirements. This general type of transmission has flexibility of control and compactness of design. Since transmissions of the fluid or hydraulic type are applied to many different kinds of machines and other forms of mechanical apparatus, both the pumps and fluid motors are made in different types and in a wide range of sizes. See Hydraulic Transmissions.

Fluorine. Fluorine is a pale greenish-yellow gas with a sharp odor. Its specific gravity is 1.265. The gas becomes liquid at a temperature of —187 degrees C. (—305 degrees F.), and the liquid becomes solid at a temperature of — 223 degrees C. (— 369 degrees F.). The most important compound of fluorine is that with hydrogen, with which it forms hydrofluoric acid (HF). Hydrofluoric acid is important because it dissolves glass, and can, therefore, be used for etching on glass. It is also used as an etching acid on metals.

Flutes. The grooves which are cut in such tools as taps, reamers, drills, milling cutters, etc., in order to form cutting edges on the tools, and at the same time provide room for the chips pro-

duced by the cutting tools when in operation, are known as *flutes*. It is important that the flutes in the various types of machinists' tools be properly shaped, and special forms of milling cutters are generally used for producing the flutes. The cross-sectional shape of the flute varies according to the type of tool. See Taps; also Hob Flutes.

Fluxes. When metals are welded or soldered together, some substance which is known as a *flux* is used to prevent oxidation and to clean the surfaces to be joined, so that a solid homogeneous joint will be obtained. Fluxes are also used in connection with the smelting of metals, to promote fluidity, prevent oxidation, and remove objectionable impurities in the form of a slag.

In ordinary steel welding, fluxes are used to protect the heated surfaces from oxidation and to dissolve any oxide that may have formed. See Soldering Fluxes; Welding Fluxes; Aluminum Welding Fluxes.

Fly-Cutter. The fly-cutter is a simple type of formed milling cutter that is often used for operations that will not warrant the expense of a regular formed cutter. The milling is done by a single tool or cutting edge which has the required outline. This tool is held in an arbor having a taper shank the same as an end-mill. The advantage of the fly cutter is that a single tool can be formed to the desired shape, at a comparatively small expense.

Flywheel. Flywheels are applied to engines and to many classes of machinery to equalize the energy exerted and the work done, and thereby prevent great or sudden changes of velocity. The extent to which velocity changes may take place is the determining factor in all flywheel design. When the energy supplied to the flywheel becomes less than the work done by the machine, the wheel will begin to turn slower and slower, because it gives up its stored-up energy to supply the deficiency. The heavier the rim and the greater its velocity, the greater the energy that may be stored up in the flywheel, and the less will be the change of speed for a given amount of energy stored up. One hundred feet per second may be regarded as a safe rim speed for cast-iron wheels made in one piece, providing the design is such that there are no severe shrinkage strains in the casting. Ordinarily, strains exist, and, therefore, about 85 feet per second is as high a rim speed as should be considered good practice. If the wheel is made in halves or sections, the efficiency of the rim joint must be taken into consideration.

Flywheel Equalizing Sets. See Equalizing Sets.

Foaming. Foaming in boilers is caused by the presence of suspended matter in the water and also, to a certain extent, by

the presence of oil. The alkaline salts of soda and potash may also produce the same result when found in the feed water in sufficient quantities. The direct cause of foaming is due to an increase in the surface tension of the water in the boiler. This requires a greater force for the bubbles of steam to burst through, and results in the churning of the top of the water into a foam, sometimes filling the steam space and passing over into the mains.

Follow-Boards. Very light or thin patterns that are difficult to keep in shape during the building process, or are apt to be rammed out of shape in the foundry, are built on wooden forms called *follow-boards*. The follow-board is usually made to conform to the inner or cope side of the pattern and is used to build the pattern on, and also in the foundry to support it in the sand. Many master patterns for stove and furnace work are made in this way.

Follow Dies. Follow dies are used for work which must be cut from the stock to the required shape, and, at the same time, be provided with holes or perforations. The principle of the follow die is that while one part of the die punches the hole in the stock, another part blanks out the work at a place where, at a former stroke, a hole or opening was punched, so that a completed article results from each stroke of the press; in reality, however, two separate operations have been performed, the operation being a progressive one in which the holes are first pierced, after which the stock moves along until the pierced section is in line with the blanking punch. Follow dies are also called "progressive" or "tandem" dies.

Follower. The name "follower" is often applied to the driven member of a gear train or other mechanism having a part that receives motion from another member and follows it; usually the "follower" in a train of mechanism is the last driven member. The follower of an engine piston of the sectional type is the plate or cover that serves to retain the piston-rings. In cam design, the follower is the part that is reciprocated by the cam surface, or the part to which the cam imparts motion. Usually the follower is provided with a roller at its end in order to reduce the contact friction to a minimum.

Follow-Rest. For turning long slender parts, such as shafts, etc., a follow-rest is often used for supporting the work. A follow-rest differs from a steadyrest in that it is attached to and travels with the lathe carriage. One type has adjustable jaws which are located nearly opposite the turning tool, thus providing support where it is most needed. Other follow-rests have, instead of jaws, a bushing bored to fit the diameter being turned, differ-

ent bushings being used for different diameters. The bushing forms a bearing for the work and holds it rigidly. Whether a bushing or jaws are used, the turning tool is slightly in advance of the supporting member.

Foot. A foot is a unit of length; 1 foot = 12 inches = 0.3048 meter = 304.8 millimeters.

Foot Candle. The unit of measurement of the intensity of the light received by an object. One foot candle is the amount of light on a surface one foot away from a standard one candlepower light source. See Candlepower.

Foot-Pound. Work is the result of the two elements, force and motion. When no motion results from the action of a force, no work is done. A jack-screw supporting a weight does no work, except when the screw is turned so as to raise the weight.

In order to calculate the work done, the magnitude of the force applied is measured in pounds and the distance moved in feet. The product of these quantities, obtained by multiplying them together, is the work in *foot-pounds*. Or, briefly stated, work = force $\times$ distance.

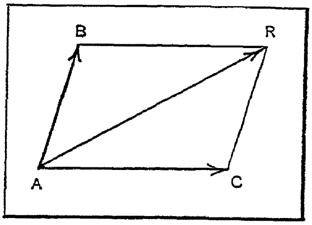
The foot-pound is called the *unit of work*, and may be defined as the work done by a force of one pound acting through a distance of one foot. In the estimation of work it is sometimes more convenient to multiply the resistance overcome by the distance, than to multiply the force applied by the distance, in which case work = resistance $\times$ distance.

Foot-Pounds per British Thermal Unit. See Heat Equivalent of Work.

Foot-Valve. A "foot-valve" is sometimes placed at the lower end of the suction pipe of a pump to prevent the suction pipe from emptying while the pump is at rest; consequently, when the pump is first started, it does not have to exhaust the air from the suction pipe, and prompt starting of the pump is secured, assuming that the foot-valve is tight enough to retain the water in the suction pipe. This valve is of especial value when the suction lift or vertical height of the pipe is considerable. When the pump is exposed to low temperatures during cold weather, it is advisable to have a drain fitted to the lower end of the suction pipe in order to empty the latter, in case the pump is to remain idle for some time and there is danger of freezing.

Force. A force, in mechanics, is defined as any cause tending to produce or modify motion. The units in which a force is usually measured are pounds or tons. A force has three characteristics which, when known, determine it. They are direction, place of application, and magnitude. The *direction* of a force is the

direction in which it tends to move the body upon which it acts. The *place of application* is generally assumed to be a point, as the center of gravity. The *magnitude* is measured in pounds, as already stated. The single force which produces the same effect upon a body as two or more forces acting together, is called their *resultant*. The separate forces which can be so combined are called the *components*. The finding of the resultant of two forces is called the *composition* of forces, and the finding of two or more components of a given force, the *resolution* of forces. If two forces applied at a point are represented in magnitude and direction by the adjacent sides of a parallelogram (*AB* and *AC* in the accompanying illustration), their resultant will be represented in magnitude and direction by the diagonal *AR* drawn from the intersection of the two component forces.



Force Diagram

Forced Draft. The forced draft method consists in forcing air under pressure into the ash-pit of a furnace, or into the retort of an underfeed stoker, and thus causing it to pass upward through the bed of fuel. It has the advantage of low first cost, and is also easily applied to old furnaces where it is desired to increase the power of the plant without installing additional boilers. One of the disadvantages of this system is that the pressure maintained in the ash-pit and furnace is liable to blow ashes and smoke into the fire-room if forced too hard. With moderate pressures, this may be avoided if care is taken to shut off the blast-pipe before opening either ash-pit or furnace doors. In admitting air to the ash-pit for forced draft, the ducts should be arranged to spread it as much as possible, and on this account it is usually introduced either through openings in the bridge wall or in the bottom of the ash-pit just inside the doors. Steel plate blowers of the centrifugal type are commonly used for forced draft. These may be of the regular form used for ventilating purposes, or of the multivane type, which is a common form of centrifugal fan having a large number of shallow vanes or blades.

Forced Draft Pressures. The pressure required for mechanical or forced draft depends upon the rate of combustion, thickness of the fuel bed, and character of the fuel used. Average conditions will usually be covered between the extremes of from 0.75 to 2 inches of water column, corresponding to 0.44 and 1.16 ounce per square inch, respectively. The volume of air or gas to be handled by the blower will depend upon whether the forced or the induced system is used. For forced draft, about 18 pounds of air is required per pound of coal, which is approxi-

mately 230 cubic feet at 60 degrees F. The higher temperature of the gases passing through the blower when induced draft is employed makes it necessary to increase this volume of air about 30 per cent, to care for the expansion.

Forced-Feed Lubrication. See under Lubricating Systems.

Forced Fits. "Forced" or "pressed fit" is the term used when a pin, shaft, or other cylindrical part is forced into a hole of slightly smaller diameter, ordinarily by the use of a hydraulic press or some other type of press capable of exerting considerable pressure. A forced fit has a larger allowance than a driving fit, and therefore requires greater pressure for assembling. The proper allowance for a forced fit depends upon the mass of metal surrounding the hole, the size of the work, the kind and quality of the material of which the parts are composed and the smoothness and accuracy of the pin and bore. Crankpins, carwheel axles, and similar parts which must be held very securely, are given forced or pressed fits rather than driving fits. The allowance per inch of diameter usually ranges from 0.001 to 0.0025 inch, 0.0015 inch being a fair average. Ordinarily, the allowance per inch decreases as the diameter increases; thus the total allowance for a diameter of 2 inches might be 0.004 inch, whereas, for a diameter of 8 inches, the total allowance might not be over 0.009 or 0.010 inch. In some shops, the allowance is made practically the same for all diameters, the increased surface area of the larger sizes giving sufficient increase in pressure. See Shrinkage Fits.

Force of Blow. The energy of a body raised to a given height and permitted to fall, as in the case of a drop hammer, is equal to the weight multiplied by the height through which it falls. Hence, the force of a blow cannot be expressed directly in pounds, but the energy with which a hammer will strike a piece of work can be expressed in foot-pounds. The average force of the blow, then, is equal to the number of foot-pounds divided by the amount of the penetration. When the force of a blow is calculated, the weight of the falling body should always be added to the energy due to the fall. If W = weight of falling body in pounds; S = the height through which it has fallen in feet; and d = distance in feet the object struck is moved (or penetrated), then:

$$\text{Average force of blow} = \frac{WS}{d} + W.$$

Force or Forcer. A "force" or "forcer" is a block of metal which forces sheet stock into every crevice in the impression of an embossing die. The term "force" is also used in connection with die-sinking, where it is often confused with the word "hub";

a *hub*, however, is a hardened steel punch used to form an impression in a die, and to use the word "force" in this connection is incorrect. A force is not employed in the making of the die, but a part of the tools for producing a finished product in an embossing die. Forces are made from different materials, depending upon the character of the work, the design of the die, and the thickness of the metal being stamped.

Forces, Couples. See Couples of Forces.

Forge Air Pressure. The air pressure for a forge commonly varies from 2 to 4 ounces per square inch, with an average of about 3 ounces. A pressure of 4 ounces at the blower has been recommended when the average number of fires does not exceed ten, and a pressure of 5 ounces when the number is more than twelve. Small forges with the blower close to them are adequately supplied with 1½ ounces pressure. If the blower is some distance away and a long discharge pipe with many bends leads to the forge, even though the latter be small, it may be necessary to carry 3 ounces pressure or more, to overcome the friction in the air ducts. The volume of free air required by the average forge fire is about 140 cubic feet per minute. The exhaust fan for a blacksmith shop should have a capacity approximately four times that of the forge blower, and should operate under a pressure of about ¾ ounce.

"Forge Welding." A heavy-duty electric resistance welding process known as "forge-welding" makes it possible to spot-weld heavy steel and iron sections heretofore considered impossible to weld with conventional equipment. With this process, such work can be spot-welded almost as easily and rapidly as sheet metal. The method consists in first applying pressure to the work and then interrupted current, after which a hammering action is superimposed on the electrode. Under high pressure and with sufficient heat, the surfaces of the work are brought into such intimate contact that when additional impact pressure and intermittent heat are applied, a "forged" weld of superior quality is obtained. To secure the forging effect and still hold the work under pressure, a compound-action "Hydro-Booster" is used. With it, a rapid succession of blows can be superimposed upon the initial constant pressure under which the work is being held.

Portable spot-welding guns can also be used for resistance "forge-welding." With such equipment, the process differs in that pressure is applied in two stages—first, a welding or contact pressure, and then a heavy "squeeze" or forging pressure.

Forging Brass. See Brass Forging.

Forging by Coining Process. This method of finishing small forgings which are required in large quantities, is by squeezing

in a powerful press equipped with suitable dies, those parts of the forgings which must be finished accurately to a given form and size. This method represents the application of the coining-press principle to the finishing of various forged parts, such as different kinds of levers, spring shackles, axle spindles, head lamp brackets, steering and fan support arms, pedals, and connecting-rods. The parts of the forging which require coining or squeezing have a small allowance to provide metal for filling the die impression, and the squeezed parts are finished to size in one stroke of the press with the same degree of accuracy as is obtained by the removal of surplus stock through cutting or machining operations. The coining type of press is used, although the term "squeezing press" has been applied to it on account of the variety of work which now comes within its range. See Cold Forging; also Cold-pressed Forgings.

Forging Hammers. See Hammers, Forging.

Forging Machines. Forging machines are made in a variety of designs, some being intended especially for bolt and rivet heading, and others for more general work. The form or shape into which a part is forged is governed by dies of the required shape and also by a heading tool or plunger which bends or upsets the heated bar of metal and forces it into the die impression. The die may have a single impression, or two or three impressions may be required in order to forge the part by successive operations. The reciprocating motion for the heading tool is obtained from a crankshaft which connects with the plunger slide by a pitman or connecting-rod.

On one type of forging machine, the crankshaft is driven through a clutch mechanism, so that the operator can control the number of revolutions the crankshaft makes before stopping, the arrangement being similar in principle to that of an ordinary punch-press. The clutch is tripped by means of a foot-treadle and the crankshaft is driven from a flywheel or gear wheel which revolves continuously. If but a single blow is required, the operator removes his foot from the treadle immediately after tripping the clutch, so that the machine stops automatically at the end of the backward stroke and after making one revolution. In case two or more continuous revolutions are required, the foot-treadle is held down until the required number of blows have been struck.

With another type of machine, what is known as a *lock* or *stop motion* device is used instead of a clutch. This mechanism is also controlled by a foot-treadle, and the device is so designed that the die mechanism is started from rest as the crankshaft, which rotates continuously, reaches the extreme end of the backward stroke. Upon releasing the foot-treadle, the movements of the

forging mechanism stop automatically. Forging machines are equipped with some form of relief mechanism, so that, in case a piece of stock should be accidentally caught between the dies, no serious damage would be done.

Forging Presses. Hydraulically-operated presses or the steam-hydraulic type are commonly used for forging large ingots, and are considered preferable to the steam hammer because they exert a steady pressure upon the forgings instead of a sharp blow, with the result that the forging action extends throughout the entire ingot, whereas the steam hammer tends to spread the surface metal without acting upon the center of the ingot to the required degree. An hydraulic press exerts a continuous pressure which forces the semi-fluid material of a forging to flow under compression, which process tends to increase the density of the material. It is thus evident that, from the standpoint of improving the quality of the material in forgings, the press is superior to the hammer. Another advantage of the forging press over the steam hammer is that, for machines of equal capacity, the press, being entirely self-contained, requires a much lighter foundation, while the hammer must have a very massive foundation under the anvil block. The first cost of the forging press is higher than that of a steam hammer, but the difference in the cost of foundation alone tends to equalize the original investment.

Forging Presses of Crank Type. Forging presses of the double-crank type are used for the manufacture of hammers, axes, pickaxes, adzes, mattocks, hoes, etc. A series of dies is arranged side by side and the part is forged in one or several heats by passing it from die to die. The slide is usually adjustable vertically, although these presses are sometimes furnished without slide adjustment and also without a clutch, for work requiring a continuous operation of the press, and where the design of the dies is such that no adjustment is needed.

Formed Cutters. When pieces having an irregular outline are to be milled, it is necessary to use a cutter having edges which conform to the profile of the work. This is called *form milling*, and the cutter a *form* or *formed* cutter. There is a distinction between a *form* cutter and a *formed* cutter, which, according to the common use of these terms, is as follows: A formed cutter has teeth which are so relieved or "backed off" that they can be sharpened by grinding, without changing the tooth outline, whereas the term "form cutter" may be applied to any cutter for form milling, regardless of the manner in which the teeth are relieved. As indicated by this distinction between "formed" and "form" cutters, these cutters are provided either with regular milling cutter teeth or with eccentrically-relieved teeth. They are

generally provided with the latter form, because in that case they can be ground on their faces without changing the form of the cutter. Form cutters are used for milling parts of special shapes to the required form. The small parts of sewing machines, guns, typewriters, and other pieces having an irregular and intricate shape are milled with formed cutters. The simplest types of form cutters are concave and convex cutters, the outline of which is a half-circle. These are used for milling half-circles, cutting half-round grooves, and forming half-round edges. Formed cutters are made in a large variety of shapes and are used for many different purposes.

Formed Cutters for Spur Gears. The invention of a milling cutter for forming gear teeth dates back prior to 1782. This cutter (now in the possession of the Brown & Sharpe Mfg. Co.) was made by Jacques de Vaucanson, a French mechanic. Evidently, the teeth were cut with chisels as they are very fine and rather crudely formed. Comparatively little is known about the types of early milling cutters used for gearing, etc., but the invention of the formed milling cutter in 1864 by J. R. Brown marked a great step in advance, as the contour of the cutting edge was not affected by successive sharpenings. This type of cutter is widely used for cutting gear teeth by the formed cutter method. See Gear-cutters.

Formex. Magnet wire insulated with a synthetic resin which is tougher and more flexible than ordinary enamel coatings and which takes up much less space. The electrical properties are as good as those of ordinary enameled wires, with higher resistance to abrasion. When severely twisted and then subjected to a temperature of 260 degrees F. for one hour, ordinary enameled wire cracks, while Formex wire is not affected. This new type of insulation has been found to have improved qualities in the actual manufacture of many electrical products. It gives the designer an opportunity to reduce the size of many products of which this wire is an integral part.

Form Grinding. The grinding of machine parts by using a broad wheel which is shaped to conform to the shape required, and without traversing either wheel or work laterally, is known as *form grinding*. The wheel is wide enough to cover the surface to be ground, and, for round work, is fed straight in, thus grinding the entire surface at the same time, without a traversing movement such as is common to ordinary cylindrical grinding. For ordinary shapes, truing of the wheel is done without difficulty, and simply requires a special truing fixture which serves to guide the truing diamond mechanically. The term "form grinding," as applied to the manufacture of machine and automobile parts, is generally used to refer to the production of both

straight and irregular-shaped surfaces. For round work, the term is used to indicate that the wheel is fed straight in without any traverse of the wheel or work. In order to differentiate between form grinding of straight and irregular surfaces, other names for the grinding of plain surfaces have been suggested, such as straight-in grinding, and wide-wheel grinding.

Formica. Formica is a non-metallic material made from sheets of cotton duck, the sheets being thoroughly impregnated with redmanol resin and made infusible and insoluble by the application of heat and pressure. An important application of formica is in making noiseless gears and pinions. Such gears are used for timing and ignition drives and on a miscellaneous variety of other machinery.

The tensile strength of formica in the direction of the laminations is 10,000 to 12,000 pounds per square inch, and the compressive strength, 24,500 pounds per square inch. The compressive strength perpendicular to the laminations is 47,000 pounds per square inch. The Brinell hardness is 34.4 and the hardness by scleroscope test, 65. The specific gravity is 1.38. The moisture and oil absorption is practically nil. The coefficient of linear expansion is about 0.00002 per degree Fahrenheit up to 150 degrees.

Formica Machining. Blanks can be cut from sheets of "Formica" either by a band saw or by trepanning tools in a boring mill or a drill press. To saw blanks, first describe a circle as a guide line, then use a 21-gage 3½-point saw running at a speed of 5000 feet per minute. The saw should be sharp, with a 1/64-inch set on both sides.

In drilling, use an ordinary high-speed drill whose point is ground to an included angle of 55 to 60 degrees. Another method is to grind the drill point slightly off center. The feed must be rapid and caution used to prevent the drill from lagging in its work, and the speed must be 1200 revolutions per minute.

For all machine operations on "Formica" gear material, provision must be made in grinding for the tools to clear themselves. For reaming, the entry of the reamer and the reaming process must be rapid. There must be no lag between the end of the reaming operation and the withdrawal of the reamer.

In turning the outside diameter and sides of blanks, the tools must be sharp and have 3 to 5 degrees more rake than is common practice for metal. A cutting speed of 750 feet per minute, which is equal to 720 revolutions per minute on a 4-inch diameter blank, is recommended. The depth of the cut can be 1/16 to ⅛ inch, but the feed should be 0.010 inch, regardless of the depth of the cut.

Teeth may be cut on a hobbing machine, shaper, or milling machine. The speed of the cutter should be 150 feet per minute,

and the feed from 0.023 to 0.040 inch per revolution. It is advisable to back up the blank to prevent fraying or breaking out of the material as the cutter comes through. The backing plates can be economically made from hard wood.

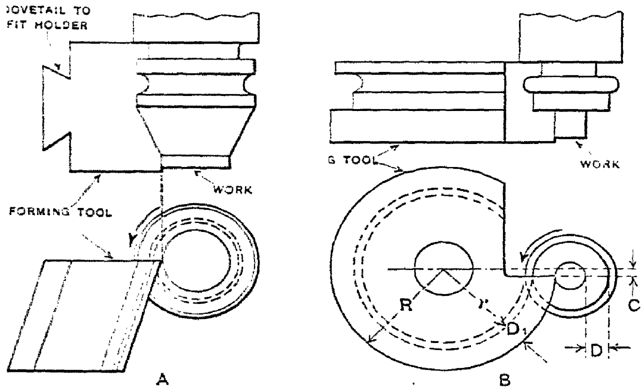
Forming Dies. Forming dies are a type of dies in which a blank is formed into a hollow shape by simply being pushed into a cavity of the required shape in the die, or a previously drawn cup is given a different shape by compressing it between a punch and die which conform to the shape desired. Drawing dies are also used for the formation of cup-shaped articles, but the drawing process differs from forming in that the stock is usually confined between two surfaces so that, when drawn radially inward from between them, no wrinkles can form. To define the difference between the two types in another way, forming dies shape the metal by compressing and bending it, whereas drawing dies so act upon a flat blank, or a previously drawn cup, that the shape is changed by drawing the metal as the punch moves relative to the die or vice versa.

Forming Lathe. What is known as a *forming lathe,* or a *forming turret lathe,* is similar to an ordinary design of turret lathe but usually has a carriage between the turret and the headstock that is arranged for carrying wide-forming tools; in some cases, there is a vertical slide at the rear, so that the forming tool may be fed in a vertical plane. Some forming and chucking lathes have a cross-slide for the turret and the latter carries the forming tools.

Forming Tools. Forming tools are made in either straight or circular shapes. Forming tools for the lathe or planer are ordinarily made flat or straight. In some cases, a flat formed blade is bolted to a holder, but tools that are to be used very little are often made solid, the formed cutting edge being machined and filed on the flat forged end of the tool. When a number of different tools are needed, it is more economical to make one shank or holder and attach separate cutters or blades of the required form. Diagram *A,* shows a *straight forming tool* of the vertical or straight-faced type. This style of tool is used on automatic turning machines, etc., especially for large work. The *circular forming tool, B,* is used in preference to the flat or straight type for many classes of work, especially in connection with automatic screw machine practice, because it is more easily duplicated after a master tool for turning it is made. The circular tool can be ground repeatedly without changing its shape. The straight form of tool may also be ground repeatedly without affecting the shape, when it is made with a formed surface which is of uniform cross-section. Forming tools are also made which operate tangentially

instead of radially; that is, the cutting edge, instead of moving in toward the center of the work, moves along a line tangent to the outside surface being formed.

Formulas. A formula may be defined as a mathematical rule expressed by signs and symbols instead of in actual words. In formulas, letters are used to represent numbers or *quantities,* the term "quantity" being used to designate any number involved in a mathematical process. The use of letters in formulas, in place of the actual numbers, simplifies the solution of problems and makes it possible to condense into small space the information that otherwise would be imparted by long and cumbersome rules. The figures or values for a given problem are inserted in the



(A) Straight Forming Tool of Vertical Type
(B) Circular Forming Tool

formula according to the requirements in each specific case. When the values are thus inserted, in place of the letters, the result or answer is obtained by ordinary arithmetical methods. There are two reasons why a formula is preferable to a rule expressed in words. 1. The formula is more concise, it occupies less space, and it is possible to see at a glance, the whole meaning of the rule laid down. 2. It is easier to remember a brief formula than a long rule, and it is, therefore, of greater value and convenience.

In chemistry, a formula is an abbreviation used to designate a chemical compound. It shows how many atoms of different chemical elements are contained in one molecule of the compound. For example, the chemical formula of ferric oxide is Fe_2O_3, which shows that one molecule of ferric oxide contains two atoms of iron, the symbol of which is Fe, and three atoms of oxygen, the symbol of which is O.

Formula Transposition. A formula can be changed or "transposed" to determine the values represented by different letters of the formula. To illustrate by a simple example, the formula for determining the speed (s) of a driven pulley when its diameter (d), and the diameter (D) and speed (S) of the driving pulley are known, is as follows: $s = \frac{S \times D}{d}$. If the speed of the driven pulley is known and the problem is to find its diameter or the value of d instead of s, this formula can be transposed or changed. Thus: $d = \frac{S \times D}{s}$.

Changing a formula in this way is known as "transposition" and the changes are governed by four general rules.

Rule 1: An independent term preceded by a plus sign (+) may be transposed to the other side of the equals sign (=) if the plus sign is changed to a minus sign (—).

Rule 2: An independent term preceded by a minus sign may be transposed to the other side of the equals sign if the minus sign is changed to a plus sign.

As an illustration of these rules, if $A = B - C$, then $C = B - A$, and if $A = C + D - B$, then $B = C + D - A$. That the foregoing is correct may be proved by substituting numerical values for the different letters and then transposing them as shown.

Rule 3: A term which multiplies all the other terms on one side of the equals sign may be transposed to the other side, if it is made to divide all the terms on that side.

As an illustration of this rule, if $A = BCD$, then $\frac{A}{BC} = D$. Suppose, in the preceding formula, that $B = 10$, $C = 5$, and $D = 3$; then $A = 10 \times 5 \times 3 = 150$, and $\frac{150}{10 \times 5} = 3$.

Rule 4: A term which divides all the other terms on one side of the equals sign may be transposed to the other side, if it is made to multiply all the terms on that side.

To illustrate, if $s = \frac{SD}{d}$, then $sd = SD$, and, according to Rule 3, $d = \frac{SD}{s}$. This formula may also be transposed for determining the values of S and D; thus $\frac{ds}{D} = S$, and $\frac{ds}{S} = D$.

If, in the transposition of formulas, minus signs precede quantities, the signs may be changed to obtain positive rather than minus quantities. All the signs on both sides of the equals sign or on both sides of the equation may be changed. For example, if $-2A = -B + C$, then $2A = B - C$. The same result

would be obtained by placing all the terms on the opposite side of the equals sign which involves changing signs. For instance, if $-2A = -B + C$, then $B - C = 2A$.

Formula Containing Power of a Number: The power of a quantity or number may be given in a formula, and it may be desirable to transpose the formula so that the number itself may be determined. The formula $V = 0.5236d^3$ is for finding the volume of a spherical body. In this formula, $V =$ the volume in cubic inches and $d =$ the diameter of the sphere. Assume that the formula is to be transposed for determining the value of d. $V = 0.5236d^3$; then $d^3 = \frac{V}{0.5236}$. It follows, then, that the cube root of d equals the cube root of $\frac{V}{0.5236}$, or $\sqrt[3]{d^3} = \frac{V}{0.5236}$. As $d = \sqrt[3]{d^3}$, then $d =$ If the volume of the sphere is 4.1888 cubic inches, then $d = \sqrt{\frac{4.}{0.5236}} = \sqrt[3]{8} = 2$ inches.

Formula Requiring Extraction of a Root: The following example illustrates how a formula may be transposed to determine the value of a quantity covered by a root sign. If A equals the length of a hypotenuse of a right-angled triangle, B equals the altitude, and C equals the length of the base, then $A = \sqrt{B^2 + C^2}$. If this formula is to be transposed for determining the value of C (lengths A and B being known), the first step is to remove the square-root sign, because C^2 cannot be transposed while it is covered by this sign. If A equals $\sqrt{B^2 + C^2}$, it follows that the square of A equals the square of $\sqrt{B^2 + C^2}$, the square of $\sqrt{B^2 + C^2}$ is the same as $B^2 + C^2$; that is, the square of the expression is obtained by simply removing the square-root sign. The reason why this is true will, perhaps, be clearer if numerical values are substituted for the letters. Suppose $B = 4$ and $C = 3$, then $\sqrt{4^2 + 3^2} = \sqrt{25} = 5$, and the square of $5 = 25$. The sum of $4^2 + 3^2$ also equals 25.

It is evident, then, that $A^2 = B^2 + C^2$. The expression has now been changed so that it can be transposed, the square-root sign having been removed. Thus, $A^2 - B^2 = C^2$, or, if the formula is written in the usual manner with the letter representing the quantity to be determined placed on the left-hand side of the equals sign, $C^2 = A^2 - B^2$. Now the procedure is the same as for the formula previously referred to for determining the diameter of a spherical body of given volume. Thus, $\sqrt{C^2} = \sqrt{A^2 - B^2}$, and as $C = \sqrt{C^2}$, it follows that $C = \sqrt{A^2 -}$

Foucault Currents. Same as Eddy-currents.

Foundations for Machinery. The materials commonly used are concrete, stone, brick, and wood in conjunction with concrete for machines subjected to considerable vertical shock. The principal characteristics of these materials are briefly as follows: Concrete is an ideal foundation material, as it becomes practically one solid piece and is much cheaper than a masonry foundation. Stone, in addition to being strong and durable, has great vibration-absorbing power, but is quite costly. Brick is not so durable as stone, but is cheaper and available everywhere. In a brick foundation, stones are usually placed under the parts of the machine which rest on the foundation. Good bricks should have plane faces, parallel, sharp edges, and sharp angles; their texture should be compact, and free from holes.

Proper Support for Machine Bed: Machine bases or frames are of two types, namely, those that have inherent rigidity and so have need of support at three points only, and those without inherent rigidity, which must be supported at intervals in order to preserve their form and maintain perfection of alignment. The average machine user attempts to confer rigidity on machines of the latter type by bolting or grouting them firmly to a foundation. Such a procedure is fatal to the satisfactory use of planers, long lathes, and other machines of that type.

The bed of such a machine should be set on a good foundation, but should never, under any circumstances, be bolted or grouted to that foundation. Instead, it should be supported on suitable wedges or other leveling devices at intervals of from three to five feet. Many shop men assume that a foundation will remain true, and that if a machine bed without inherent rigidity be grouted to the foundation, it will add to the stiffness and strength of the bed and eliminate vibration.

Foundations sometimes settle from 1/4 to 1/2 inch, and planer beds, for example, have been forcibly sprung over 1/4 inch by being grouted firmly to a foundation that settled. As a result, the ways were no longer straight, the table vees touched only at the high spots, and the bearing surfaces were soon destroyed. If this machine had been set on leveling blocks, placed at about four-foot intervals, and the leveling blocks had been drawn up as often as necessary to compensate for the settling of the foundation, the planer would have remained accurate.

Types of Machine Foundations: Machine foundations may be divided into rock-supported foundations, pile-supported foundations, and floating foundations. Rock-supported foundations are concrete or masonry structures which rest on rock or hard clay of such bearing power that the foundation does not settle measurably under the load of the machinery. Such a foundation may be in one piece or it may be a series of piers. If a foundation of

this kind is obtainable at a reasonable cost, it is the best sort of machine foundation, but even a rock-supported foundation is subject to some seasonal movement, and long beds or frames must not be grouted or bolted to it.

When the foundation, because of the cost or for other reasons, cannot be carried down to the rock, it may be laid upon piles, columns, or beams that are rock-supported. Such a foundation is less subject to seasonal movement, but is more likely to settle at points where it carries concentrated loads.

Floating Foundations: A floating foundation is one laid on an ordinary earth surface which has been properly leveled and compacted. The foundation must be stiff enough so that it transmits the weight equally to all parts of the surface, and large enough so that the distributed load does not exceed the safe bearing strength of the earth. It is usually in the form of a properly designed reinforced concrete slab.

Even a good floating foundation may settle, and provision must be made for keeping the machinery level. If the foundation carries only fixed weights, it can support a number of machines with only slight seasonal changes and very little settling. If, however, the loading varies from time to time, as, for instance, if the slab supports a column supporting a traveling crane, independent slabs should be provided for machines without inherent rigidity, while a common slab will do for a number of machines whose frames have inherent rigidity.

When a floating foundation is laid near a pile or rock-supported foundation, many masons anchor it to the pile or rock-supported foundation, but the foundation is then not so good as it would be if it were free from such support, for if the earth settles ever so slightly, the foundation will no longer be true, while if the rock foundation be subject to moving loads, the floating slab will continually vary in its level.

Loads on Soils and Rocks: Information about the bearing capacities of soils and rocks is not only useful in structural engineering, but also of value under certain conditions in connection with the installation of very heavy machinery requiring foundations. The ultimate resistance of various soils and rocks will be given in tons per square foot: Natural earth that is solid and dry, 4 to 6 tons; thick beds of absolutely dry clay, 4 tons; thick beds of moderately dry clay, 2 tons; soft clay, 1 ton; gravel that is dry, coarse, and well packed, 6 to 8 tons; soft, friable rock and shales, 5 to 10 tons; sand that is compact, dry, and well cemented, 4 tons; natural sand in a clean dry condition, 2 to 4 tons; compact bed-rock, northern red sandstone, 20 tons; compact bed-rock, northern sound limestone, 25 tons; compact bed-rock granite, 30 tons.

Foundry Coke. See Coke.

Foundry Crane. This is a jib crane frequently used in foundry work. It is generally of heavy construction.

Four-Stroke Cycle. See Cycles of Internal Combustion Engines.

Fox Lathe. The Fox lathe was first built by George H. Fox, some time between 1843 and 1859. Distinguishing features of the Fox lathe are a compound side-rest (which, in later years, was usually surmounted by a tool turret) and a screw chasing attachment, known originally as "Nason's patent screw-chasing apparatus." This consists of a tool-holder clamped to a longitudinal round bar which is mounted in bearings so that it can both oscillate and slide endways. A half-nut, fixed to the bar, is brought into engagement with a short lead-screw when the operator pulls the chasing tool against the work. The Fox lathe is primarily a brass-working lathe, and is widely used in the manufacture of brass valves, gas fixtures, plumbing supplies, and other brass goods.

Fractional Horsepower Motor. According to the American standard, a fractional horsepower motor is a motor built in a frame smaller than that having a continuous rating of one horsepower, open type, at 1700 to 1800 revolutions per minute. Such motors are widely used for all types of electrical appliances, refrigerators, oil burners, small tools, etc.

Free Air Capacity of Compressor. See Air Compressor Capacity.

Free-Cutting Stock. The term "free cutting" is applied to stock which may readily be machined and which does not form long, tough chips that tend to clog cutting tools. This free-cutting property is especially important in connection with automatic screw machine and turret lathe practice.

Free-cutting Brass: The standard specification No. 72 of the Society of Automotive Engineers for free-cutting brass rod is as follows, the composition being in percentages: Copper, 60 to 63; lead, 2.25 to 3.25; iron, maximum, 0.15; other impurities, maximum, 0.50; zinc, remainder.

Free-Cutting Steels: There are several classes of free-cutting steels. S.A.E. composition No. 1112, often called "screw stock," has excellent machining properties. This steel has from 0.08 to 0.16 per cent carbon and from 0.60 to 0.90 per cent manganese. S.A.E. No. X1112 has a similar composition, but with a higher sulphur content which improves the finish and machinability. It is used only when production, speed, and finish are especially important. The open-hearth screw stock (S.A.E. Nos. 1115 and

1120) are somewhat inferior to Nos. 1112 and X1112 in machining properties but possess a much better combination of strength and toughness, and are more dependable for casehardened parts and for such operations as bending, swaging, riveting, and forming.

Freeze-Out. In blast furnace operation, the term "freeze-out" means that the iron and slag in the hearth has set in a solid mass, so that it is impossible to open the tap holes. This trouble is remedied by increasing the heat of the furnace until the metal is again melted.

Freezing Mixtures, Radiator. See Anti-freezing Mixtures.

French Thermal Unit. See Calorie.

French Thread (S.F.) The French thread has the same form and proportions as the American standard (formerly U. S. standard). This French thread is being displaced gradually by the International Metric Thread System.

Frequency. The frequency of an alternating electrical current is the number of cycles or periods per second. The product of 2π times the frequency is called the *angular velocity* of the current. Sixty cycles is the standard lighting frequency in the United States. If a lower frequency is used, fluctuations in the light are likely to occur. At 40 cycles, this flickering is not essentially objectionable, but at 25 cycles, it is quite perceptible, and this frequency is not used for lighting service except in an emergency.

Frequency Changer. Many high-speed motor-driven portable tools and also certain classes of wood-working and metal-working machines are operated by high-frequency current due to the high speed, light weight, and compactness of the motor drive. An essential part of a high-frequency installation is a frequency changer. Frequency changers convert the power of an alternating-current system from one frequency to another, without a change in the number of phases, or in the voltage. They are either used for obtaining, from a low-frequency system, a frequency high enough for lighting purposes, or as a means of interchanging power between systems operating at different frequencies.

Frequency-changer sets consist either of an induction motor driving a synchronous generator, or a synchronous motor driving a synchronous generator, the latter combination being the most common, especially where two systems are to be tied together and where reversible sets are required.

Another type of frequency changer utilizes a vibrator type of converter. When operated from a 110-volt, 60-cycle power supply,

it delivers a 110-volt output at any one of ten different frequencies which can be selected by means of a tapped switch.

Frequency Converter. A frequency converter is a frequency changer in which the windings carrying the currents of different frequency are in the same magnetic field. Thus, a motor-driven induction generator arranged for polyphase excitation of the stator can be so utilized. When the rotor is stationary, it acts as a transformer and delivers an output at the same frequency as the supply; when driven as a generator, it has an output consisting of a voltage and frequency due to transformer action plus a generated voltage and frequency depending upon its speed. Such a converter is usually employed only when the desired output frequency is 25 per cent or more above that of the input.

Friction. Friction is the resistance to motion which takes place when one body is moved upon another and is generally defined as "that force which acts between two bodies at their surface of contact, so as to resist their sliding on each other." The force of friction, F, bears (according to the conditions under which sliding occurs) a certain relation to the pressure between the two bodies; this pressure is called the *normal pressure* N. The relation between force of friction and normal pressure is given by the *coefficient of friction,* generally denoted by the Greek letter μ. Thus:

$$F = \mu \times N, \text{ and } \mu = \frac{F}{N}.$$

For well-lubricated surfaces, the *laws of friction* are considerably different from those governing dry or poorly lubricated surfaces.

1. The frictional resistance is almost independent of the pressure per square inch, if the surfaces are flooded with oil.

2. The friction varies directly as the speed, at low pressures; but for high pressures the friction is very great at low velocities, approaching a minimum at about two feet per second linear velocity, and afterwards increasing approximately as the square root of the speed.

3. For well-lubricated surfaces, the frictional resistance depends, to a very great extent, upon the temperature, partly because of the change in the viscosity of the oil and partly because the diameter of the bearing increases with the rise of temperature more rapidly than the diameter of the shaft, thus relieving the bearing of side pressure.

4. If the bearing surfaces are flooded with oil, the friction is almost independent of the nature of the material of the surfaces in contact. As the lubrication becomes less ample, the coefficient

of friction becomes more dependent upon the material of the surfaces.

When a body rolls on a surface, the force resisting the motion is termed *rolling friction.* This has a different value from that of the ordinary, or sliding, friction. Let W = total weight of rolling body or load on wheel, in pounds; r = radius of wheel, in feet; f = coefficient of rolling friction. Then:

$$\text{Resistance to rolling, in pounds} = \frac{W \times f}{r}.$$

The coefficient of rolling friction varies with the conditions. For wood on wood it may be assumed as 0.002; for iron on iron, from 0.002 to 0.005; iron on granite, 0.007; iron on asphalt, 0.012; iron on wood, 0.018.

Friction Clutch. A friction clutch is used for transmitting power from one machine member to another by means of frictional contact between members attached to the driving and driven machine parts. These clutches are made in many different designs, there being, however, four types that predominate; the conical clutch, the radial-expanding friction clutch, the contracting-band clutch, and the friction disk clutch. Friction clutches are used when it is desired to have a smooth and gradual engagement and disengagement of the driving and driven members.

Friction Dial Feeds. See under Power Press Ratchet Dial Feeds.

Friction Gearing. The term "friction gearing" is commonly applied to that type of gearing consisting of a driver made of some substance such as fiber or leather and arranged to operate by rolling in contact with a metallic driven wheel. The driving and driven wheels may be either cylindrical for driving parallel shafts or conical for driving shafts at an angle; when speed variations are required, a small driving disk may be arranged to revolve in contact with the side of a comparatively large driven disk, which also provides for reversing the rotation merely by shifting the driver to the opposite side of its central position on the driven disk. With the latter arrangement the axes of the driving and driven members are at right angles, and pure rolling contact is not obtained when using a driver of cylindrical form, since it makes contact with the driven disk at various diameters. Friction gearing provides a smooth, uniform drive, but toothed gearing is superior for most purposes because of its positive action and greater power-transmitting capacity. The latter may also be designed to transmit much more power, and at the same time insures maintaining the same relative positions between the driving and driven members, which is important for many classes of mechanism.

"Friction Head" for Lathes. The geared friction head or headstock for turret lathes, etc., has back-gears and friction clutches for engaging either the direct cone-pulley drive or the back-gearing. Many modern designs are equipped with geared headstocks instead of a cone-pulley and either a single driving pulley or a direct-connected motor drive.

Friction Safety Coupling. This is a coupling in which one member is driven by friction, so that in case the power to be transmitted exceeds the normal requirements, the coupling will permit the driven member to slip.

Friction Saw. With a friction saw the "cutting" is done by a rapidly revolving soft steel disk, the edge of which is nicked slightly by means of a special chisel. When this disk is brought into contact with the part to be cut, a very rapid burning and abrading action occurs owing to the high speed and the resulting friction and heat. This disk is usually driven by a direct-connected electric motor which is mounted upon a horizontal carriage that is moved forward for feeding the disk against the work. These friction saws are used in steel mills and structural shops, etc., for cutting rails and bars of various shapes while cold. The disks have a rim speed of 24,000 feet per minute or higher and they cut very rapidly. The only sharpening necessary is to occasionally renick the edge of the disk. The best material from which to make friction disks for this purpose is soft steel having a carbon content of about 0.15 per cent; ordinary boiler plate or a brand of steel known as "soft flange-steel," which contains very little sulphur, gives satisfactory results. The disks should be turned true and roughened crossways on the edge with chisel cuts 1/16 inch deep and about ¼ inch apart.

Friction-Screw-Driven Press. Friction screw or percussion presses are used for forging, hot-pressing, and stamping purposes. The driving mechanism of this type of press has one pulley with a friction wheel so arranged that either of two friction wheels may be shifted to engage the rim of the heavy central friction- or fly-wheel, attached to a vertical screw. By means of this screw, the ram of the press is raised or lowered. The main feature claimed for this class of press is the cumulative blow delivered, all the energy of the flywheel being utilized as it comes to a dead stop; the operation is essentially that of pressing rather than that of a sharp blow or of hammering. Other advantages claimed for this type of press are that it provides for an "elastic" blow, the drive not being positive, and that, therefore, this design does not require bearings, shafts, etc., of as large dimensions as are required in presses with a positive drive

Fuel, Calorific Value. See Combustion of Coal; also Calorimeters.

Fuel, Coal Dust. See Coal Dust as Fuel.

Fuel, Colloidal. See Colloidal Fuel.

Fuel Oil. Fuel oil has been defined as any liquid or liquefiable petroleum product burned for the generation of heat in a furnace or firebox, or for the generation of power in an engine, exclusive of oils with a flash point below 100° F., Tag closed tester, and oils burned in cotton or woolwick burners. Fuel oils in common use fall into one of four classes: (1) residual fuel oils, which are topped crude petroleums or viscous residuums obtained in refinery operations; (2) distillate fuel oils, which are distillates derived directly or indirectly from crude petroleum; (3) crude petroleums and weathered crude petroleums of relatively low commercial value; (4) blended fuels, which are mixtures of two or more of the three preceding classes.

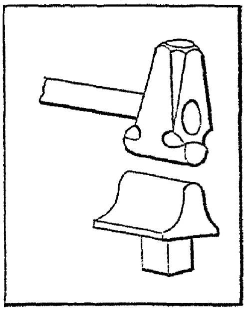
Fuel Oil, Coal and Gas Equivalents. One gallon of fuel oil equals 13.1 pounds of coal, equals 160 cubic feet of natural gas. One barrel of fuel oil equals 0.278 ton of coal, equals 680.6 cubic feet of natural gas. One pound of fuel oil equals 1.75 pounds of coal, equals 21.3 cubic feet of natural gas. One pound of coal equals 0.763 gallon of oil, equals 12.2 cubic feet of natural gas. One ton of coal equals 3.6 barrels of oil, equals 24,500 cubic feet of natural gas. The heating value of the average mid-continent fuel oil having a Baume gravity of 26.9 is 19,376 British thermal units per pound of oil, and 143,950 British thermal units per gallon of oil.

Fuel Oil Heating Values. In order to determine the calorific values in British thermal units per pound of fuel oils, sixty-four samples of petroleum oils ranging from heavy crude oil to gasoline, representing the products of the principal oil fields in the United States, have been examined for calorific power. It was found that the oils varied in fuel value from about 18,500 to 21,100 B.T.U. per pound. In general, the decrease in calorific power with an increase in specific gravity is regular, so that the relation between the specific gravity and the heat value may be expressed approximately by means of a simple formula, as follows: B.T.U. per pound $= 18{,}650 + 40 \times$ (Number of Degrees Baume — 10).

Fuels, Combustion Elements. See Combustion Elements in Fuels.

Fuller Cell. A Fuller cell is a primary cell or battery in which the zinc anode, which is in the form of a cone, is placed in a

porous cup containing a little mercury. This cup is then filled with the electrolyte, which may be either dilute sulphuric acid or a solution of common salt, and is placed in a glass jar which is filled with a depolarizer. The carbon cathode is then put in place. In a standard Fuller cell which has been widely used, the depolarizer is composed of 6 ounces of sodium bichromate, 17 ounces of sulphuric acid, and 56 ounces of water, which ingredients are heated together, forming chromium peroxide. The cell is used for open or closed circuits and has an electromotive force of from 2 to 2.1 volts.



Fullers

Fullers. Fullers are used by blacksmiths for making grooves, breaking-down work, part of which is to be drawn down to smaller dimensions, and for a variety of other purposes. They have a fillet at the point where the light section joins the heavier stock and are made in pairs, top and bottom to match. (See illustration.) Top fullers are fitted to wooden handles and are used in the same manner as sets. Bottom fullers are made with shanks or stems to fit the hardie hole in the anvil.

Fun. A Japanese measure of weight, equal to 0.375 gram or 5.79 grains. One fun is divided into 10 rins.

Function. In mathematics, a function is a quantity or expression which depends for its value upon the value given to other quantities called independent variables or arguments. The circumference of a circle, for example, is a function of its diameter; when the length of the diameter is varied, the circumference varies also. In a table, the values by means of which the table is entered are known as arguments, while the tabulated values obtained from the table are functions.

Functional Gage. See Gage Classification.

Functions of Angles. In order to introduce the values of the angles in calculations of triangles, use is made of certain expressions called trigonometrical functions or functions of angles. The names of these expressions are: sine, cosine, tangent, cotangent, secant, and cosecant. These expressions are usually abbreviated as follows: sin = sine; cos = cosine; tan = tangent; cot = cotangent; sec = secant; cosec = cosecant.

The *sine* of an angle equals the opposite side divided by the hypotenuse. The *cosine* of an angle equals the adjacent side divided by the hypotenuse. The *tangent* of an angle equals the opposite side divided by the adjacent side. The *cotangent* of an angle equals the adjacent side divided by the opposite side. The

secant of an angle equals the hypotenuse divided by the adjacent side. The *cosecant* of an angle equals the hypotenuse divided by the opposite side.

It should be noted that the functions of the angles can be found in this manner only when the triangle is right-angled. The secant and cosecant, being merely the values of 1 divided by the cosine and sine, respectively, are not often used in calculations, and are not always included in tables of angular functions. See also Law of Sines and Cosines.

Funt. A Russian measure of weight, equal to 0.4095 kilogram, or 0.9028 pound avoirdupois. Forty funts equal one pood.

Furlong. A surveyor's length measure; 1 furlong = 10 chains = 220 yards = 660 feet = 201.17 meters.

Furnaces. Furnaces are used in connection with many different operations and processes, such as the hardening of steel, annealing, melting of metals, drying and baking, or for heating parts preparatory to a rolling, forging, or drawing operation. The furnaces used for these different classes of work vary greatly both in regard to size and design. The fuel may be oil, gas, coal, or coke, or electricity may be utilized for producing the necessary heat. The general classification is commonly based upon the position of the firebox or combustion chamber relative to the heating chamber, and these general classes are subdivided into types which are designated, usually, by terms indicating either the method of heating or the kind of work for which the furnace is intended. The name, in some instances, may also indicate some other characteristic constructional feature, as in the case of a *single-end furnace,* which has but one door or opening for the insertion and removal of work, or a *double-end furnace,* which has doors at both ends to provide for a progressive movement of the parts being heated.

Side-fired Furnaces: The side-fired type of furnace is very commonly built with grates for the use of coal. For the use of oil fuel, suitable openings are made in the side walls, and the grates are covered with two or more courses of firebrick. By adjusting the air supply to give a long flame, it is possible to obtain a fairly uniform temperature across a heating chamber from 5 to 7 feet wide. Chambers 8 feet wide have given satisfactory service for some purposes. The conducting of the waste gases under the heating chamber floor will assist in heating the bottom of the work and increase the efficiency of the furnace. This type, with various modifications, has been used extensively for the annealing of brass, copper, and German silver.

End-fired Furnaces: The heat distribution in end-fired furnaces is quite similar to that in the modified form of the side-fired

furnace with the two fireboxes at one end. This type is practicable for heating chambers as large as 10 feet square, if the requirements of uniformity are not too strict. Oil fuel is sometimes introduced through the rear wall in the same manner as through the side wall of the side-fired type. This construction was formerly used for annealing brass, but is now more commonly applied to plate heating, etc., where the mass of work is not deep, or, if deep, is relatively short so that the heating chamber can be made short and not require the false arch. Large furnaces for forge work are relatively long, with the stack or a flue at the end opposite the firebox and with doors at the side for the introduction of the work.

Under-fired Furnaces: One of the most common types for small furnaces is the under-fired type. The same principles are sometimes applied to larger furnaces where the firing can be done below the mill floor line, as in a pit or basement. In heat distribution, this is the ideal type of furnace. For high-temperature work, this type has the disadvantage of subjecting the roof of the firebox or combustion chamber to an unusually severe condition, due to the relatively high temperature on top of it as well as underneath. This makes necessary the use of a very refractory material for that portion of the furnace, if the temperature required is high.

Over-fired Type: An over-fired furnace is one in which the combustion chamber is above the heating chamber arch, the combustion gases being carried to the heating chamber through perforations in this arch, and leaving the furnace at the bottom of the hearth. This type of furnace is not commonly used, as the arch construction is expensive and delicate. As heated gas has a tendency to rise, extra draft must be used with an over-fired furnace, to draw the heat down. For extremely high furnaces, this type can be used in conjunction with the under-fired type. Its construction is also suitable for furnaces requiring removable hearths which are mounted on wheels, where there is no possibility of using the under-fired type.

Internally-fired Type: In some cases the heating chamber and the combustion chamber can be combined. This arrangement is applicable to forge furnaces, rod and rivet heaters, etc., in which an intense heat is required, and the work will not be seriously affected by the direct action of the flame. Melting furnaces of some types are also internally fired. It is but rarely desirable to have the flame proper strike directly against the cold work, as combustion is thereby retarded and soot is often deposited on the work, particularly when oil fuel is used. This type is largely confined to the use of gas and oil fuel.

Hearth-fired Type: In a hearth- or heating-chamber-fired furnace, the initial heat of combustion enters directly into the heating chamber. This type of furnace is usually constructed to allow the gases to come into direct contact with the work, and on account of fuel impurities it is not desirable for the heat-treatment of finished products. In carburizing, however, the work is protected and excellent and economical results can be obtained if there are proper flue outlets. This type of furnace can also be used for annealing if the product later undergoes machining. The removable type of hearth can also be installed in this furnace. See also Electric Furnaces; Oil-burning Furnaces.

Furnaces, Brickwork. There are two prime essentials in furnace brickwork. The first is a quality of brick suited to the required service. The second is the laying of the brick with thin joints. Ordinary practice in laying common brick is utterly unsuitable for firebrick. Standard "9 straight" firebrick, uniform in size and straight within 1/8 inch, should be dipped in a thin mixture of fireclay and water and laid with only what adheres to the bricks, and be rubbed to bed them in the wall, with the bricks in actual contact and the clay mixture merely filling the spaces left by what unevenness there may be on the surfaces. For joints which are necessarily thicker, the clay mixture should be thickened with sea sand, ground firebrick, or carborundum fire-sand which will not shrink as much as the clay. Lime should never be used in the laying of firebrick. Portland cement is used by some masons and is probably desirable as a binder in laying No. 2 quality firebrick where the temperature to which it will be exposed is less than 2500 degrees F. For high temperature duty particularly, the fireclay with which the bricks are laid should be of the same (or better) quality as the bricks, and preferably of the same brand.

Furnace Temperature Control. The temperature of heat-treating furnaces may be controlled in several different ways: First, the furnace operator may take the pyrometer readings and regulate the furnace according to his own judgment; second, the operator may simply adjust the furnace to maintain a given temperature according to signals from a man in charge of the temperature control for all the heat-treating furnaces; third, the signals of the furnace operator may be controlled automatically by a special form of pyrometer which is previously set for whatever maximum and minimum temperatures are desired; and fourth, the control may be entirely automatic. When the control is by some method of signaling, either colored lights or a bell may be used. If lights are employed, there are generally three—a red, white, and green combination being common. These lights

are placed near the furnace. The red light may show that the temperature is too high, the white light that it is correct within certain limits (possibly 15 or 20 degrees) and the green light that it is too low. Lights are sometimes used in combination to vary the signals. For instance, when a furnace is loaded with work, the temperature is reduced considerably, the amount depending upon the size of the work and the number of pieces inserted. When the temperature has increased to a certain point, two lights may be switched on to show that it is still considerably below the required temperature, and then one light may be used to show that it is approaching the correct temperature but is still somewhat low. Finally, a different light may indicate that the correct temperature has been reached. See also Pyrometers.

Fuses in Electrical Circuits. An electric fuse is simply a conducting element of such dimensions that it will melt at a predetermined current value, and thus break the circuit and prevent a dangerous temperature increase due to abnormal current conditions. Although arranged in many forms, fuses are simply metal strips or wires that melt, or fuse, when the current reaches the predetermined value. They are divided into two classes: (1) Those designed to protect the circuit and apparatus against both short circuits and definite amounts of overloads. (2) Those designed to protect the system only against short circuits. To the first class belong link and enclosed fuses of the National Electric Code that open on 25 per cent overload. To the second belong the expulsion fuses, which blow at several times the current they are designed to carry continuously. Fuses differ from plain overload circuit-breakers in that they are governed by both the time and quantity of the current, while the overload circuit-breaker is governed solely by the quantity of the current.

Fusible Metals. Fusible metal is the name applied to certain metal alloys generally composed of bismuth, lead, and tin, and sometimes also containing cadmium, which possess the property of melting at comparatively low temperatures. One of the earliest discoveries of a metal alloy which would melt at a low temperature was that of Newton, and the metal known as *Newton's fusible metal* contained 50 parts of bismuth; 31.25 parts of lead; and 18.75 parts of tin. This metal melts at a temperature of 201 degrees F. Another of the early fusible metals was discovered by Darcet. This alloy contained 50 per cent of bismuth; 25 per cent of lead; and 25 per cent of tin; it melts at a temperature of about 200 degrees F. The addition of cadmium produces an alloy which melts at a still lower temperature. An alloy containing 50 parts of bismuth; 25 parts of lead; 12.5 parts of tin; and 12.5 parts of cadmium will melt at a temperature as low as 149 degrees F.

By the addition of mercury to the metal discovered by Darcet, the melting point may be reduced to as low as 113 degrees F.

Fusible metals are used for a number of purposes where an alloy that will melt at a low predetermined temperature is required, as in automatic sprinkler heads, in fuses in electric circuits, and for fusible plugs in steam boilers. In automatic fire sprinklers, the rise of temperature resulting from a fire, will melt this metal and the water will be liberated. In steam boilers, fusible plugs are inserted in the furnace crown sheets as a safeguard in case the water level should fall too low. When the fusible plug is no longer in contact with the water, it will be heated to such a temperature that it will melt and allow the steam to escape, thus giving warning of the condition existing in the boiler. See Wood's Metal.

Fusion. The term "fusion" applies to the melting of a solid body, or to the changing of the state of a body from the solid to the liquid condition. It has been established, beyond doubt, that all substances can be transformed into a solid state at some temperature, but, in the case of gases, the temperature must be exceedingly low. It has also been established that all solid substances can be fused or melted and transformed into the liquid state, provided the temperature is high enough. Of the chemical elements, it appears that carbon will stand the highest degree of heat without melting. When changing from the solid to the liquid state, a certain amount of heat is used to accomplish this change. This heat does not raise the temperature of the body and is called the *latent heat of fusion.* This heat is applied to the body at the melting point and is absorbed by the body, although its temperature remains nearly stationary during the whole operation of melting. The latent heat of fusion varies for different substances.

G

Gage. Any tool or instrument used for taking measurements might properly be called a "gage," but this term, as used by machinists and toolmakers, is generally understood to mean those classes of tools which conform to a fixed dimension and are used for testing sizes, but are not provided with graduated adjustable members for measuring various lengths or angles. There are exceptions, however, to this general classification. Gages may be made or set to measure one or more dimensions, and they are used for determining if manufactured parts have been made to agree with prescribed dimensions. If a gage is provided with means for measuring the maximum and the minimum dimensions to which a given piece may be made, it is known as a "limit gage" because it is the means of determining if the part is made within the predetermined limits set for it.

Gages are used in interchangeable manufacture, where a number of similar parts are to be made, all of which may be measured by the same gage and the accuracy of which, within the prescribed limits, may thereby be assured. As the name implies, *working gages* are used by the workmen at the bench or machine in gaging the work as it is being made. *Inspection gages* are used by the inspectors in checking the product to determine if it has been properly made to the required dimensions. *Reference gages* are used for testing or checking the inspection gages from time to time, to make sure that they have not become unsuitable, through wear or otherwise, for the use for which they are intended. These very general classes of gages are made in a large variety of designs and sizes. See Limit Gages; Master Gages; Reference Gages; Temperature Standards for Gages.

Gage-Block Adhesion. A remarkable property of precision gage blocks is their adhesiveness to one another. When wrung together they will resist separation in a direction at right angles to the faces in contact, with a force considerably greater than the atmospheric pressure on the area of contact. This phenomenon has caused some to believe that actual molecular adhesion takes place when surfaces that are nearly perfect planes are brought into intimate contact. The error of this theory has been revealed by investigations showing that the adhesion results from the presence of a very thin liquid film. Some blocks of hardened steel were prepared, each weighing 1½ ounces and having surfaces of 0.7 square inch polished flat to within a millionth of an inch of accuracy, and these were used to test the adhesive properties of

many liquids. The contact faces were carefully freed from moisture and grease with alcohol before being coated with a very thin film of the liquid under test. When wrung together while perfectly clean, they fell apart, under their own weight; in order to separate blocks which were held together by films, a force ranging from 17 pounds for Rangoon oil to 22 for lubricating oil, 29 for turpentine, and 35 for condensed water vapor was necessary. After washing the hands with soap, blocks rubbed on them showed adhesion as high as 90 pounds. There was no adhesion from volatile liquids, such as alcohol and benzine; and very little from viscous liquids, such as glycerine and glucose. The microscope showed that the films, drawn out in thin lines, covered only a tenth or less of the metal faces. From varied experiments it appeared that in the case of paraffin film, for instance, the 27 pounds required to part the plates included about one pound due to atmospheric pressure, one to surface tension and 25 pounds to the actual tensile strength of the liquid. The tensile strength of water seemed to be as high as 443 pounds per square inch.

Gage-Blocks. Precision gage-blocks are used in checking or establishing very accurate measurements in machine shops and tool rooms. Gage-blocks are small blocks of steel. Each block in a set has a given thickness or length, and the size of each block is marked on it. The dimension marked on any block represents the distance between two parallel surfaces on opposite sides. If the block, for example, is a 1-inch size, this means precisely 1 inch, within, at most, a few millionths of an inch variation. In other words, precision gage-blocks are practically errorless. Many gage-blocks do not vary from the given size more than two millionths of an inch. The measuring surfaces are not only exact as to the distance between them, but these surfaces must also be flat and parallel with practically no error. Gage-blocks are sold in sets. By combining two or more precision gage-blocks a large range of extremely accurate dimensions can be obtained. The blocks are combined in this way when there is no single block in the set of exactly the size wanted. Gage-blocks or combinations of them are very generally used in machine building plants as ultimate standards of reference for checking inspection or working gages and other precise measuring and gaging equipment.

The total number of gage-blocks in commercial sets vary. One very complete set contains 85 blocks. By placing together different combinations, about 120,000 different gaging lengths are obtainable. Frequently, a given dimension can be obtained by two or more combinations of blocks either for checking one combination against another or for use on different jobs.

Selecting Gage-blocks to Obtain a Given Dimension: Since many dimensions can be obtained by using two or more combina-

tions of blocks, it is preferable, as a general rule, to use the simplest combination or the one requiring the smallest number of blocks. For example, suppose the dimension is 1.9504 inches. Since there is no one block having this dimension, it is necessary to use a combination. Begin by selecting a block for the right-hand figure. Since this is 4, it is necessary to begin by using the 0.1004-inch size. Following the decimal point in the given dimension, we have 0.950; hence, the entire decimal part of the dimension can be obtained by adding the 0.850-inch size (0.1004 + 0.850 = 0.9504). Then, by adding the 1-inch size, the dimension is completed, as shown below at the left. Another method of obtaining this same gaging length is to use a combination of four blocks as shown at the right.

First block	0.1004	First block	0.1001
Second block	0.850	Second block	0.1003
Third block	1.000	Third block	0.950
		Fourth block	0.800
Total dimension	1.9504	Total dimension	1.9504

Gage Classification. The gages used in machine-building plants may be included in one of the following classes, depending upon the use to which the gage is put.

Master Gages: These gages are used only as checks for inspection or working gages. The master for a ring gage is a plug, and the master for a plug gage is usually another plug from which a measurement may be taken for comparison. A basic size gage may also be known as a "master."

Inspection Gages: Gages of this class are used by the inspector to check work coming either from the factory or from outside sources.

Working Gages: Working gages are used in machine-building plants for checking the work, either in a semi-finished or finished state. They are made to a tolerance within the inspection gage tolerance, or larger than the minimum dimension of the work and smaller than the maximum dimension.

Functional Gages: Functional gages are used to test the functional relation of parts, as for example the relation of two such mating parts as a spline shaft and a hole.

Gages for Materials. The thicknesses of sheet metals and the diameters of wires conform to various gaging systems. These gage sizes are indicated by numbers, and in MACHINERY'S Handbook and in other engineering handbooks, will be found tables giving the decimal equivalents of the different gage numbers. Much confusion has resulted from the use of gage numbers, and

in ordering materials it is preferable to give the exact dimensions in decimal fractions of an inch. While the dimensions thus specified should conform to the gage ordinarily used for a given class of material, any error in the specification due, for example, to the use of a table having "rounded off" or approximate equivalents, will be apparent to the manufacturer at the time the order is placed. Furthermore, the decimal method of indicating wire diameters and sheet metal thicknesses has the advantage of being self-explanatory, whereas arbitrary gage numbers are not. The decimal system of indicating gage sizes is now being used quite generally, and gage numbers are gradually being discarded. Unfortunately, there is considerable variation in the use of different gages. For example, a gage ordinarily used for copper, brass and other non-ferrous materials, may at times be used for steel, and vice versa. The gages specified in the following are the ones ordinarily employed for the materials mentioned, but there are in some cases minor exceptions and variations in the different industries.

Gages for Rods. The Brown & Sharpe or American Wire Gage is used for rods of non-ferrous metals, such as brass, copper and aluminum. Stub's Steel Wire Gage is used to some extent for tool steel, drill rod and wire, and the Twist Drill and Steel Wire Gage is used for twist drills and steel drill rods.

Gages for Sheet Metals. The U. S. Standard Sheet Metal Gage is used by the manufacturers of commercial iron and steel sheets or plates, including planished, galvanized, tinned and terne plate; black sheet iron; blue annealed soft steel; steel plate; hot-rolled sheet steel; cold-rolled sheet steel; hot-rolled monel metal; and cold-rolled monel metal. The American or Brown & Sharpe Wire Gage is used for sheets of brass, phosphor-bronze, aluminum and German silver. The Birmingham Wire Gage is used for strip steel, steel bands, hoop steel, crucible spring sheet steel, and sheet copper. The Zinc Gage is used for sheet zinc only.

In England the Birmingham Gage legalized in 1914 is used mainly for iron and steel sheets and hoops. This 1914 Birmingham Gage differs from the older Birmingham Wire Gage (see wire gages in MACHINERY'S Handbook). Another older gage known as the Birmingham Metal Gage is used for brass sheets. For aluminum sheets, the Imperial Wire Gage is used in England.

Gages for Tubing. The Birmingham Wire Gage is used for the following classes of tubing: Seamless brass, seamless copper, seamless steel, and aluminum. The Brown & Sharpe Wire Gage is used for brazed brass and brazed copper tubing.

Gages for Wire. The Brown & Sharpe or American Wire Gage is generally used in the United States for all bare wire of

brass, copper (except bare copper telephone wire) phosphor-bronze, German silver, aluminum, and zinc; for resistance wire of German silver and other alloys; for insulated wire of aluminum and copper. The Steel Wire Gage (also known as (1) Washburn & Moen, (2) American Steel & Wire Co., (3) Roebling, and (4) National Wire Gage) is used for bare wire of galvanized and annealed steel and iron (except telephone and telegraph), and also for spring steel wire. The American Steel & Wire Co.'s Music Wire Gage is used for music wire. The Birmingham Wire Gage sizes are very generally used for iron and steel telephone and telegraph wires, but the sizes of bare copper telephone wires, usually conform in the United States, to the Standard Wire Gage used in England. This Standard Wire Gage (also known as the Imperial Wire Gage and as the English Legal Standard) is used in England for all wires. The abbreviation S. W. G. is sometimes used for Standard Wire Gage, also the abbreviation N. B. S. for New British Standard Wire Gage. This gage was legalized in Great Britain in 1883.

Gage Temperature Standards. See Temperature Standards for Gages.

Gage Terms and Definitions. The definitions which follow apply to certain terms used in connection with the American Gage Design Standards.

American Gage Design Standard: The caption "American Gage Design Standard" has been adopted to designate gages made to the design specifications promulgated by the American Gage Design Committee.

Anvil: The gaging member of a snap gage when constructed as a fixed nonadjustable block, or as the integral jaw of the gage.

Adjustable Snap Gage: An external caliper gage employed for the size control of external dimensions, comprising an open frame, in both jaws of which gaging members are so held that one or more pairs can be set and locked to any predetermined size within the range of adjustment.

Solid Snap Gage: An external caliper gage employed for the size control of external dimensions, comprising an open frame and jaws, the latter carrying gaging members in the form of fixed, parallel, nonadjustable anvils.

Taper Lock: Term designating that construction in which the gaging member has a taper shank, which is forced into a taper hole in the handle.

Annular Plug Gage: A shell type plug gage in which the gaging member is in the form of a ring, the external surface of which is the gaging section, the central portion of the web being machined away for the purpose of reducing weight, ball handles being provided for convenience in handling. This construction is

employed for plain and thread plug gages in the ranges above 8.010 inches.

Plain Cylindrical Plug Gage: A complete unthreaded internal gage of single- or double-ended type for the size control of holes. It consists of handle and gaging member or members, with suitable locking means.

Progressive Cylindrical Plug Gage: A complete unthreaded internal gage consisting of handle and gaging member in which the "go" and "not go" gaging sections are combined in a single unit secured to one end of the handle.

Reversible Plug Gage: A plug gage in which three wedge-shaped *locking prongs* on the handle are forced into corresponding *locking grooves* in the gaging member by means of a single through screw, thus providing a self-centering support with a positive lock.

Thread Plug Gage: A complete internal thread gage of either single- or double-ended type, comprising handle and threaded gaging member or members, with suitable locking means.

Plain Ring Gage: An unthreaded external gage of circular form employed for the size control of external diameters. In the smaller size it consists of a gage body into which is pressed a *bushing* that is accurately finished to size for gaging purposes.

Thread Ring Gage: An external thread gage employed for the size control of threaded work, means of adjustment being provided integral with the gage body.

Thread Ring Gage Locking Device: Means of expanding and contracting the thread ring gage during the manufacturing or resizing processes. It also provides an effectual lock.

Gage Tolerance. According to the practice of a prominent manufacturer of gages, a tolerance equal to 10 per cent of the tolerance on the work is generally allowed on ordinary working and inspection gages. Thus, if the work tolerance is 0.005 inch, the gage tolerance equals 0.0005 inch for both the working and inspection gages. There is a difference, however, between the maximum and minimum dimensions of the working and inspection gages. The minimum size of the working gage is made 10 per cent of the tolerance *larger* than the minimum size of the inspection gage, and the maximum size of the working gage is made 10 per cent of the tolerance *smaller* than the maximum size of the inspection gage.

Gaggers. In molding, if a body of sand that must be lifted away with the cope extends below the parting, it is strengthened by the use of gaggers. These are usually L-shaped pieces of cast or bar iron. The upper part of the gagger, when reamed tightly between the cope bars, helps to support a hanging body of sand.

Gallon. See Liquid Measure.

Gallotannic Acid. A lustrous, faintly yellowish, amorphous powder. It is soluble in water and alcohol; decomposes at 210 degrees C. It is also known as acid tannic. Its chemical composition is $C_{10}\ H_{14}\ O_9$.

Galvanizing. Galvanizing, in general, is the process of coating one metal with another; the name, however, is more especially applied to the coating of iron or steel products with zinc to prevent corrosion by excluding moisture. Tin and lead are sometimes used as coating materials, but are less effective. Aluminum fulfills all the requirements of a good coating better than any of the commercial metals, but zinc is used because of its lower cost. Iron parts are galvanized by dipping them in molten zinc; this is the process generally known as *galvanizing.* The galvanizing of wire, whether in the form of netting or single wire, is a continuous process, so that the factor of speed is introduced. The amount of zinc deposited can be regulated to a nicety by varying the temperature or speed, or both. The wire passes through a flux and then through the molten metal, and emerges through a part of the bath continually skimmed from oxide. Zinc used for galvanizing should not contain more than 0.5 per cent of iron. It will absorb from 1 to 4 per cent, but each per cent absorbed raises the melting temperature of the bath, so that the zinc becomes thick and pasty; the absorption of iron from the articles being coated and from the sides of the container requires frequent skimming of the bath.

Galvanometer. The galvanometer is an instrument for detecting or measuring electric currents, and is a term generally applied to instruments indicating electric currents on a scale having divisions of arbitrary units, as opposed to the instruments known as "ampere-meters," which give directly the strength of a current in amperes. A great number of different instruments have been devised both for direct and alternating current. The principle on which one of the types of direct-current galvanometer works is based upon the fact that a small magnet, when suspended in the center of a coil of wire through which current is passed, has a tendency to place its magnetic axis in the direction of the magnetic field of the coil at that point. The galvanometer may also be constructed with a suspended coil and a fixed magnet. In alternating-current galvanometers, the instrument may be made by suspending, within a coil of insulated wire, a needle of soft iron placed with its axis at an angle of 45 degrees to the axis of the coil. When an alternating current passes through the coil, the soft iron needle has a tendency to place itself in the direction of the axis of the coil. Other types have also been devised. A

ballistic galvanometer has its movable parts damped as little as possible, so as to make it adaptable for quick measurements, such as electric charges or discharges. The deflection is, therefore, proportional to the quantity of electricity rather than to the current.

Galvo-Cleen. This compound forms a bond that enables newly galvanized metal to be painted without a primer, the compound providing a non-reactive zinc-phosphate coating. Galvanized metal, zinc die-castings, and alloys having a large percentage of zinc can be cleaned and prepared for painting by the application of this compound.

Gang Drilling Machine. See Drilling Machines.

Gang Milling. A great deal of the work done on milling machines (especially the horizontal types) is machined by a combination or "gang" of two or more cutters mounted on one arbor. This is known as gang milling. If a plain cylindrical cutter were placed between two side mills a gang cutter would be formed for milling several surfaces. This would not only be a rapid method, but one conducive to uniformity when milling duplicate parts.

Gang or Multiple Dies. When large numbers of blanks are required, *multiple* or *gang dies* are sometimes used. These dies have a number of duplicate punches with similar openings in the die-block and cut as many blanks as there are punches, at each stroke of the press. The term "gang" die is often applied to a follow die; this usage is generally conceded to be incorrect, however, as the word "gang," as used in mechanics, ordinarily means a combination of similar tools so arranged as to act simultaneously for producing duplicate parts.

Gang Planing. When a number of duplicate parts have to be planed, much time can often be saved by arranging the castings in a straight row along the platen so that they can all be planed at the same time. This method, called gang planing, enables a number of parts to be finished more quickly than would be possible by machining them separately, and it also insures duplicate work.

Gang Presses. Power presses of the gang or multiple type are especially designed for operating long narrow dies requiring considerable power, such as those used for gang-punching rivet holes in sheets for boilers and tanks, riveting dies, corrugating and forming tools, etc. A typical press of the gang type has a gap frame and double-crank drive for the slide. The cam-actuated stripper is generally used in connection with these presses. This form of stripper permits the use of much shorter and more durable punches than can be employed with stationary strippers.

Moreover, the stripper comes down upon the metal and straightens it (if not too thick), holding it while punching and stripping takes place. After the punches have moved up through the sheet, the stripper also ascends.

Gang Presses of Double-action Type: These presses are designed for cutting, drawing, and stamping a large number of small shells at each stroke. They are equipped with several types of automatic feeds and operate very rapidly. Such presses are generally used for the manufacture of bottle caps and similar articles, when a large output is necessary. One type is provided with an automatic chain-feed, stripper, and an automatic sweep for the discharge of shells, and produces fourteen shells per stroke. It will handle sheets of decorative stock in such a way that the printed pattern will register accurately with the dies. The sheet is placed on the feed table, is automatically gripped, carried to the dies, and the bottle caps and scrap are automatically discharged separately.

Gantry Crane. This is a crane similar to a traveling crane except that the overhead bridge is carried at each end by a trestle which itself travels on longitudinal tracks on the ground. A trolley on the bridge provides for the transverse motion. Gantry cranes erected in shop yards alongside of a building are sometimes supported by an overhead rail at the end of the bridge next to the building and on a trestle traveling on the ground at the other end.

Gantt Bonus System. This is a method of wage payment in which the workman receives his regular daily wage irrespective of the amount of work done and, in addition, he receives a bonus which is some percentage of his hourly rate, if he performs a given job in a predetermined time. See Bonus Wage System.

Gap Presses. This type of power press is built with a gap or throat through the frame so that the stock can be fed from side to side or from front to back. With the exception of the gap, this type of press is similar to straight-sided or double-crank presses.

Garnet. The garnet is a natural abrasive that is extensively used in woodworking industries, in the manufacture of leather goods, and for other purposes. It is a mineral that varies widely in chemical composition and color. The variety most commonly used as an abrasive is known as "almandite," which is of a deep-red color. This color, however, changes as the material is broken into smaller particles, becoming lighter. Most of the garnet used for abrasive purposes in the United States is obtained in New York state. The almandite garnet is found in the form of crystals in a gangue rock, from which it is separated

by crushing and concentrating mechanically in a device known as a jig concentrator.

The hardness of garnet, according to Mohs's hardness scale, is about 7. According to this same scale, the diamond, which is the hardest substance, is represented by 10, while talc, which is the softest mineral, is represented by 1. Garnet seems to possess just the right degree of strength, hardness, and brittleness for cutting wood fiber and producing a smooth finish. Its brittleness insures new cutting edges being constantly presented to the work, and the cutting edges remain sharp, owing to its degree of hardness. As garnet has a low point of fusion, it is impossible to bond it in the form of wheels, except by using vegetable and silicate of soda bonds.

Gas Absorption by Liquids. Many liquids have a capacity for absorbing a certain amount of gas. The quantity thus absorbed varies with the liquid and the gas. Many gases, for example, are readily absorbed by water; thus, water will absorb its own volume of carbonic-acid gas, over two times its volume of chlorine, and 430 times its volume of ammonia. Water will not, however, absorb more than 5 per cent of its volume of oxygen. The weight of gas that a given volume of liquid will absorb is proportionate to the pressure, but as the volume of a given mass of gas is proportionately less as the pressure increases, the volume which a given amount of liquid will absorb at a certain temperature is constant, whatever the pressure. Water absorbs its own volume of carbonic-acid gas at atmospheric pressure. If the pressure is doubled on both the gas and water, the latter will still absorb its own volume of the gas under the higher pressure, but, in that case, the density of the gas is doubled and, consequently, double the weight of the gas is dissolved. The quantity of gas absorbed increases as the temperature is lowered. One of the most important instances of the absorption of gases by liquids is met with in the absorption of acetylene by acetone; the latter liquid absorbs, at 60 degrees F. and 180 pounds pressure per square inch, 300 volumes of acetylene gas. This property of acetone makes it possible to safely store and transport acetylene gas in steel containers.

Gas and Coal Fuel-Oil Equivalents. See Fuel Oil, Coal and Gas Equivalents.

Gas and Oil Engines. See Internal Combustion Engines.

Gas Casehardening Process. See Nitrogen Hardening.

Gas Coke. Gas coke is obtained as a by-product in gas works. This coke is produced rapidly at a low heat; it is of a dull black color and ignites readily.

Gas Furnace Fuel. Gas-fired furnaces use either natural, artificial, or producer gas. Some gas furnaces are equipped with an automatic apparatus which operates in conjunction with a pyrometer for controlling the temperature to within a few degrees of a given point. The air supply is generally obtained from a positive blower, although when a compressor is installed, for operating pneumatic tools, the air is sometimes utilized for the furnaces by interposing reducing valves to diminsh the pressure. Artificial gas is more expensive than oil, but is cleaner, and the installation of supply tanks, such as are required for oil, is avoided. Producer gas obtained from a separate plant is not economical unless there is a considerable number of furnaces; in that case, however, it may be the cheapest fuel obtainable. When oxidation or the formation of scale is particularly objectionable, furnaces of the muffle type are often used, having a refractory retort in which the steel is placed so as to exclude the products of combustion. These muffles must be replaced very frequently and more fuel is required than when an oven type of furnace is used.

Gas, Helium. See Helium Gas.

Gashing. The term "gashing" is used especially with relation to the cutting of the teeth in worm-gears. In this operation, a milling cutter is employed having approximately the outline of a normal cross-section of the teeth of the worm. Gashing is simply a roughing process preparatory to *hobbing* the gear teeth. After the gashing operation, the teeth are finished to conform to the exact shape of the worm by revolving the blank in unison with a cutter known as a *hob*, and which is practically a duplicate of the worm, but fluted and relieved so as to provide cutting teeth.

This preliminary gashing operation is done when worm-gears are cut on ordinary milling machines but it is not required when using machines especially adapted for worm-gear cutting.

Gaskets for Joints. A gasket may be defined as a ring of some compressible material, inserted between two metallic surfaces which are to be tight against leakage of water, steam, or other liquid or gaseous fluid. The gasket forms a loose compressible film between the elements of the joint and, in this way, makes the joint leak-proof. Gaskets are usually made of sheet rubber (or rubber in combination with some other substance, such as asbestos or graphite), sheet copper, sheet lead, cork, and paper. When the steam pressures are comparatively high, ordinary rubber gaskets are liable to be injured by the heat and, in such cases, copper or lead is frequently used. Gaskets containing rubber should not be used in the joints of gasoline engines or in gasoline supply piping, because rubber is slightly soluble in gasoline. For

pipes which convey gasoline, it is better to use unions which have ground joints instead of joints made by gaskets. Gasket material composed largely of brass wire gauze and asbestos is frequently used, and, if properly fitted and provided with graphite facing, such gaskets are very durable.

Gasoline. Gasoline is a refined petroleum naphtha which by its composition is suitable for use as a carburant in internal combustion engines. The general refineries' practice is to call everything gasoline which distills up to a temperature of 410 degrees F. The specific gravity may vary from 54 degrees Baume for heavy crude oils up to 61 degrees for unusually light crude oil. A heavy gasoline must be blended to make it satisfactory for general use. The initial boiling point of ordinary commercial gasoline varies from 80 degrees F. to 160 degrees F.; the end boiling point, from 368 degrees F. to 450 degrees F., and the specific gravity from 56 degrees to 61 degrees Baume. Gasoline contains 129,060 British thermal units per gallon, or 20,750 per pound. The freezing temperature is 50 degrees F. below zero. Gasoline readily vaporizes when exposed to the air of any temperature down to 15 degrees F. below zero. The vapor is nearly three times as heavy as air, and when mixed with the proper quantity of air becomes violently explosive. If confined where there is poor ventilation, this mixture will sometimes remain in the explosive condition for several months. The vapor will ignite from an open flame, a spark from a grinding wheel or from a sufficiently heated surface.

Gasoline Cracking Process. See Cracking Process.

Gas Producers. The gas producer is an apparatus for the manufacture of combustible gas from solid fuel. Briefly described, it consists of a space enclosed by refractory materials and containing solid fuel (coal, coke, wood, or peat) at a high temperature, through which air and steam are caused to pass. The reaction between the air and steam and the fuel, which latter consists largely of carbon, causes the formation of hydrogen and carbon monoxide. These two combustible gases, mixed with the inert nitrogen introduced by the air, form a gas known as "producer gas."

Gas producers are classified as "pressure producers" and "suction producers." In pressure producers, the air and steam are introduced into the producer at a pressure greater than that of the atmosphere, and the gas leaves the producer at a pressure slightly above the pressure of the outside air. In the suction producer, the air and steam are drawn into the producer by creating a partial vacuum in it, and the gas leaves the producer at a pressure lower than that of the atmosphere. Generally speak-

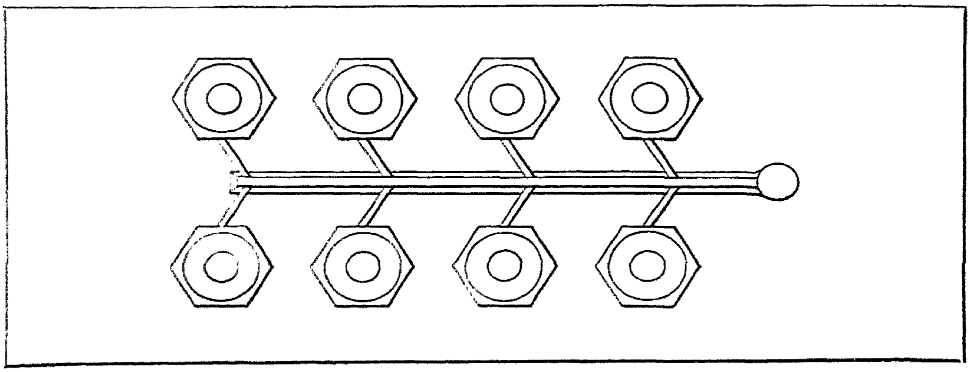
ing, pressure producers are commonly used in metallurgical work, where the gas is employed for heating furnaces, since it is easier to handle and transmit the gas when it is at a pressure slightly above, rather than below, that of the atmosphere. Suction producers are used principally for furnishing the fuel gas for gas engines, because the gas is cleaner; the suction of the engine piston furnishes the necessary partial vacuum required for drawing from the producer the quantity of gas needed for the engine. The commercial designs of producers may be classified as five distinct types: The up-draft pressure type; the down-draft pressure type; the up-draft suction type; the down-draft suction type; and the combined up-and-down-draft suction type.

Gas Production. Manufactured gas may either be coal gas, water gas or oil gas. In producing *coal gas* certain kinds of bituminous coals are distilled in retorts or ovens and the resulting gases are condensed, scrubbed, washed and purified to remove water vapor, tar, ammonia and sulphur. *Water gas* is produced by an intermittent process in which a bed of anthracite coal or coke is raised to a high temperature by an air blast and then steam under pressure is blown through the fuel, forming carbon monoxide, hydrogen and a small amount of carbon dioxide by reaction with the carbon in the fuel. The so-called *blue water gas* thus obtained has a heating value of about 300 B.T.U. per cubic foot and almost no luminosity when burned in an open flame. "Mixed gas" is usually understood to be a mixture of carbureted water gas and coal or coke-oven gas, and it is supplied in many cities in the United States where requirements permit. Where oil is cheap and coal expensive, as on the Pacific Coast, oil gas is produced as it is more economical than the coal or water gases. In making oil gas, oil alone is used as fuel.

Natural Gas: Natural gas usually is associated with deposits of coal or petroleum and it is found trapped in various strata of the earth, principally in loose sandstone formations or in shale seams and cavities. Ordinarily natural gas is associated with petroleum and occupies the space above the oil in the petroleum-bearing sand. Occasionally gas is not accompanied by oil, in which case the gas composition is somewhat different.

Gas Pyrometers. In gas pyrometers, the change in pressure of a gaseous mass kept at a constant volume is used to indicate the temperature. Pyrometers based on this principle occupy considerable space and are not suitable for ordinary practical work. They are used only for standardizing other pyrometers.

Gas Turbine. A gas turbine is a rotary prime mover or power-producing machine in which the combustion gases of an explosive mixture of gas and air impinge at high pressure upon



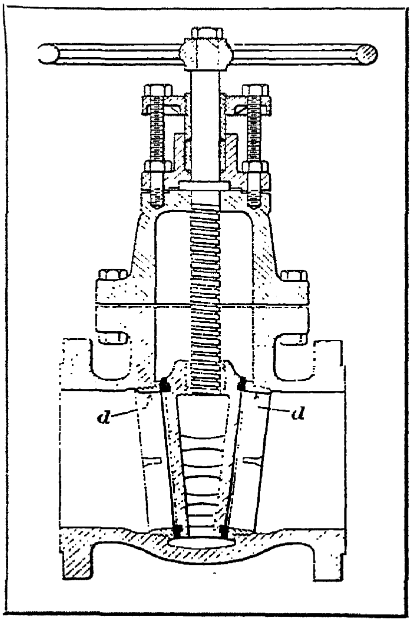
Gate of Hexagon Nuts

the blades of a turbine wheel or rotor in a manner similar to that in which steam impinges upon the blades of a steam turbine. A number of experimental designs have been constructed.

Gas Welding. See Oxy-acetylene Welding.

Gated Patterns. Where large numbers of small castings are required, it is more economical to make metal patterns and mount them on a gate. This means that a number of patterns are fastened to a pattern that forms the opening for pouring the metal and the channels for conveying it to the individual molds. The illustration shows a "gate" of hexagon nuts.

Gate Valves. A gate valve, as its name implies, is constructed on the principle of a gate, which is raised or lowered by the action of a screw or other mechanical means. Several forms of gate valves are used; some close the valve opening with a box wedge, others with sectional gates having seats parallel or wedge-shaped, and still others with gates formed like a solid wedge. One of the principal advantages in the use of a gate valve is that the opening is such that it does not obstruct the flow of liquid to any great extent. Valves of this kind are particularly desirable when the resistance to the flow of liquid should be as small as possible. Some gate valves are so made that the stem which raises the valve is



Gate Valve

threaded at its upper end, and passes up through the hub of the handwheel. In the form shown (see illustration), the stem is threaded at its lower end and enters a nut in the upper part of the wedge-shaped valve gate. The seat in the body of the valve is formed by rings which are inserted in both the gate and body, as indicated at *d* in the illustration. These rings are in each case made of soft metal, and are firmly imbedded and then faced off in such a way that the tapers coincide.

Gear Castings, Bronze. The following recommended practice for bronze and brass castings for gears, has been approved by the American Gear Manufacturers' Association.

For *spur and bevel gears*, use the hard cast bronze S.A.E. No. 62 or the well-known 88-10-2 mixture, keeping within the following limits: Copper, 86 to 89 per cent; tin, 9 to 11 per cent; zinc, 1 to 3 per cent; lead (maximum), 0.20 per cent; iron (maximum), 0.06 per cent. Good castings made from this bronze should give the following minimum physical characteristics: Ultimate strength, 30,000 pounds per square inch; yield point, 15,000 pounds per square inch; elongation in 2 inches, 14 per cent.

For *bronze worm-gears*, two alternative analyses of phosphor-bronze are recommended, namely, S.A.E. No. 65 and No. 63. The S.A.E. No. 65, called phosphor-gear bronze, has the following composition: Copper, 88 to 90 per cent; tin, 10 to 12 per cent; phosphorus, 0.1 to 0.3 per cent; lead, zinc, and impurities (maximum), 0.5 per cent. Good castings made from this alloy should give the following minimum physical characteristics: Ultimate strength, 35,000 pounds per square inch; yield point, 20,000 pounds per square inch; elongation in 2 inches, 10 per cent.

Composition for the S.A.E. No. 63 alloy, called leaded gun metal, is: Copper, 86 to 89 per cent; tin, 9 to 11 per cent; lead, 1 to 2.5 per cent; phosphorus (maximum), 0.25 per cent; zinc and impurities (maximum), 0.50 per cent. Good castings made of this alloy should give the following minimum physical characteristics: Ultimate strength, 30,000 pounds per square inch; yield point, 12,000 pounds per square inch; elongation in 2 inches, 10 per cent.

These alloys, especially No. 65, can be chilled for increasing the hardness and refining the grain. No. 65 is to be preferred for use with worms of great hardness and fine accuracy. No. 63 is to be preferred for use with unhardened worms.

For bronze *bushings for gears*, S.A.E. No. 64 is recommended, having the following analysis: Copper, 78.5 to 81.5 per cent; tin, 9 to 11 per cent; lead, 9 to 11 per cent; phosphorus, 0.05 to 0.25 per cent; zinc (maximum), 0.75 per cent; other impurities (maximum), 0.25 per cent. Good castings of this alloy should give the following minimum physical characteristics: Ultimate strength,

25,000 pounds per square inch; yield point, 12,000 pounds per square inch; elongation in 2 inches, 8 per cent. See English Gear Bronze; also Phosphor-Bronze.

Gear-Chucking Methods. The followng methods are employed for holding gears while grinding the shaft holes: (1) Holding the gear by the outside diameter or tops of the teeth. (2) Using rolls between the teeth—sometimes called the "pitch-line control method." (3) Using jaws of special shape, which make contact with the gear at the bottom of the tooth spaces—a method known as "root control." The first method cannot be used with success when the gears are to run at high speeds, because of the possible lack of concentricity between the hole and the working surfaces of the teeth. The second method, while requiring the use of a more expensive chuck, is much more satisfactory than the first, provided the spacing of the teeth has not been affected by hardening and the rolls are uniform in diameter and supported by a truly concentric surface. A slight variation in the width of the tooth spaces, however, makes a considerable difference in the relative position of the rolls, owing to the acute angle made by the tooth surfaces near the pitch line where the rolls bear. This has been considered, by some manufacturers, a serious objection to this method. For the average line of work, the third method is recommended. The jaws of the chuck engage the bottom of the tooth spaces, so that inaccuracies of spacing, due to hardening the teeth, do not affect the accurate holding of the gear; furthermore, it is a very simple matter to maintain the accuracy of the jaws by simply truing the contact points whenever necessary.

Gear-Cutters. The series of formed cutters ordinarily used for cutting spur gears contains eight cutters for each pitch. These eight cutters are adapted to cut all gearing from a pinion of twelve teeth to a rack. Each cutter may be used for a limited range of tooth numbers. The number of teeth and the pitch for which a cutter is adapted are always marked on the cutter. These cutters are numbered from 1 to 8 and the different numbers are adapted for spur gears of the following sizes: Cutter No. 1, for gears having teeth varying from 135 to a rack; No. 2, gears with from 55 to 134 teeth; No. 3, from 35 to 54 teeth; No. 4, from 26 to 34 teeth; No. 5, from 21 to 25 teeth; No. 6, from 17 to 20 teeth; No. 7, from 14 to 16 teeth; and No. 8, from 12 to 13 teeth. If it is assumed that the diametral pitch of the gear to be cut is 12, and the required number of teeth, 90, a No. 2 cutter of 12 diametral pitch would be used, the No. 2 shape being selected because it is intended for all gears having teeth varying from 55 to 134.

Intermediate Series: When greater accuracy of tooth shape is desired to insure smoother or quieter operation, an intermediate series of cutters having half numbers is used. The half numbered cutters made by the Brown & Sharpe Mfg. Co., are for the following ranges of tooth numbers: Cutter No. 1½, 80 to 134 teeth; No. 2½, 42 to 54; No. 3½, 30 to 34; No. 4½, 23 to 25; No. 5½, 19 and 20; No. 6½, 15 and 16; and No. 7½, 13 teeth. There are seven cutters in this series, No. 8½ being omitted since this would be for a pinion with less than 12 teeth.

Gear-Cutting Attachment. When it is necessary to cut comparatively large spur gears on a milling machine, a gear-cutting attachment is preferable to the regular dividing-head. This attachment, in its usual form, is similar to a dividing-head, but is larger and heavier in construction. If the gear is too large to clear the machine table when mounted between the centers, the centers are sometimes raised far enough to provide clearance for the gear blank by placing parallel blocks underneath the index-head and tail-center. If the gear blank is so large that it will not pass under the cutter arbor with the table in its lowest position, it may be possible to cut the gear by using an "under-cutting attachment." The centers are raised far enough to provide room for the cutter beneath the gear, and the arbor is supported by a special outboard bearing.

Gear-Cutting Processes. The gear-cutting processes commonly utilized for producing different types of gears may be divided into three general classes. One includes the use of tools or cutters which form gear teeth by reproducing the shape of the cutter itself; in another class are the generating processes whereby the proper tooth curves are formed through relative motions of the tool and work, as when a straight-sided cutting tool generates the required tooth curves due to the relative motions imparted to the gear blank and cutter. The third general classification includes the use of templets or master formers, which control the path followed by the cutting tool, and consequently the curvature of the gear tooth; this method is applied chiefly to the cutting of very large gears.

In the application of these processes the gear teeth may be formed by (1) milling the teeth with cutters conforming to the shape of the spaces between the teeth; (2) milling the teeth with a cutter of the hob type, which represents a rack in the axial plane and is used in generating the tooth curves; (3) planing with a circular cutter which has teeth like a gear and serves to generate the tooth curves as the cutter and gear blank revolve in unison; (4) planing with a tool that takes a series of cuts across the side of the tooth and is guided by a templet or former as it is gradu-

ally fed inward; (5) planing with a tool that conforms to a single rack tooth and generates the tooth curves as it moves laterally after each stroke, while the gear blank receives an indexing movement that causes each tooth to mesh properly with the traversing tool; (6) planing with a tool which is similar to a short section of a rack and is used in generating tooth curves as the gear blank rotates relative to the rack cutter; and (7) planing the teeth of the gear by the use of a formed tool which is of the same shape as the tooth spaces. See following paragraphs on gear-cutting processes and machines; also Automatic Gear-cutting Machines; Bevel Gear Generating Processes; Hobbing Process.

Gear Cutting by Generating Process: In order to illustrate the principle of the generating process of gear-cutting, assume that a finished spur gear having teeth of correct form is revolved while in contact with a blank, which for purposes of illustration is assumed to be made of some soft, plastic material. The nature of this rolling action would be to generate teeth on the plastic blank. Thus, the teeth on the finished gear, as they roll into contact with the blank, form teeth having the curvature required for meshing properly with the generating teeth. Now, if this tooth forming or generating gear were hardened, and its teeth given suitable clearance, the cutter thus formed could be used to generate teeth in a cast-iron or steel blank, provided the cutter had a reciprocating action parallel to the axis of the blank, while both cutter and blank slowly revolved together, the same as two gears in mesh. This method of using a gear-shaped cutter is employed on a well-known type of machine.

Another method of generating gear teeth is to give the gear blank a rolling movement relative to a rack-shaped cutter. It is possible to employ either a gear-shaped or a rack-shaped cutter, because a rack can be designed, for any system of interchangeable gearing, which will mesh correctly with a range of gear sizes of the same pitch. Moreover, all gears that will mesh properly with the rack will also mesh with one another. Generating processes of cutting gears are based on this interchangeable feature, which also accounts for the fact that one cutter may be used for cutting various sizes of gears of the same pitch. The cutter represents either a rack or a gear of the interchangeable series, and it cuts or generates teeth as the uncut gear blank and cutter are given movements, relative to each other, similar to a finished gear running in mesh either with a rack or with another gear, depending upon the type of cutter that is used. See also Bevel Gear Generating Processes.

Gear-Finishing Machines. When very precise gears are required as in the automotive, aircraft, and certain other indus-

tries, special gear-tooth finishing machines are used. There are several different types. One type (which is used extensively) takes a very light shaving cut to correct errors left by the gear-cutting machine. The general practice is to semi-finish the gears on some generating type of gear cutter and then use a finishing machine. A lapping operation may also be applied to gears which, prior to heat-treatment, were finished on a machine of the shaving type. This dual finishing process is applied when extreme precision is essential. A third type of gear-finishing machine operates by rolling the gear to be finished in contact with a master burnishing gear. In using a shaving type of machine, the cutting action may also be accompanied by more or less burnishing, depending upon the angular position of the cutting tool as explained later. A fourth general method of finishing gears, especially after hardening, is by grinding. Finishing methods have been developed for different classes of gears, such as external and internal spur and helical gears, bevel gears, spiral-bevel gears, and hypoid gears.

Rotary Gear-Shaped Type of Finishing Cutter: A common type of machine for finishing by taking a light shaving cut is equipped with a cutter having either helical or spur teeth. Shaving tools of the spur type may be used for helical gears up to 15 degrees helix angle, and the helical type of shaving tool for larger helix angles. The faces of the cutter teeth have closely spaced grooves separated by narrow lands to form a number of cutting edges. This cutter meshes with and rotates the gear to be finished, and this rotation is accompanied by a longitudinal motion to bring the entire face of each gear tooth in contact with the cutter. The angular position of the cutter is adjustable and the axes of the cutter and gear lie in planes which intersect, usually at angles of 10 to 15 degrees. This *crossed axis* method is important not only in gear-tooth shaving, but also in finishing by lapping. The angularity is conducive to greater accuracy because of the increased guiding action between cutter and work and a better cutting action due to improved clearance for the cutting edges. As the angle is reduced below 10 degrees, the shaving or cutting will be accompanied by increased burnishing action. When the angle is zero, this is known as the *parallel axis method.* This may be employed to prevent interference with a shoulder, but it is preferable to use the crossed-axis method whenever possible. When the cutter axis is parallel or nearly so, much greater contact pressure is required which explains the increase in burnishing action.

In finishing a gear, there is a longitudinal reciprocating movement and also a feeding movement to bring the cutter and gear closer together for removing the required amount of metal. The

reciprocating movement is equal to or slightly greater than the face width of the gear being finished. Each reversal is accompanied by a reversal of cutter rotation, so that both faces of each tooth are in contact with the cutter during each cycle. After each cycle, an automatic feeding movement of possibly 0.001 to 0.003 inch occurs until the machine is stopped automatically after a predetermined number of cycles.

Rack Method of Crossed-Axis Gear-Tooth Shaving: With this method, the teeth of a semi-finished gear are accurately generated while in mesh with a reciprocating rack-shaped cutter made to conform with the basic rack of the gear to be finished. The faces of the rack teeth have narrow parallel grooves with intervening lands which form the cutting edges. The gear to be finished is mounted upon centers and meshes with the rack which is given a reciprocating movement like a planer table. Racks of the straight type may be used for helical gears up to 30 degrees helix angle. For larger angles, an angular rack must be used—either right- or left-hand, as required. The gear-holding head is swiveled so that the angle between the gear axis and rack equals the helix angle (unless this angle exceeds 30 to 33 degrees). Since the plane of the rack's movement is at an angle to the gear axis, the result is a shaving action due to the crossed-axis relation between the rack and work. There is a cross-feed to reciprocate the gear across the rack and a down-feed for removing enough metal for finishing. The various movements are stopped automatically after a predetermined number of finishing strokes. This type of machine is especially adapted to mass production.

Finishing Gears by Lapping: The lapping process is an inexpensive method of correcting the slight errors which may be caused in hardening finished gears. Lapping may be described as a refining process. The lap (or laps) resembles a gear. For example, the type of lap used for helical gearing also has helical teeth. Some machines have a single lap; others, two laps; and a third type, three laps. The lap (or laps) rotates with the gear, and a lapping compound is applied by brush or pump. The crossed-axis principle is applied in lapping as in finishing by the shaving method.

A Michigan two-lap type of machine is designed to hold the work on centers and between front and rear laps. The machine has a relatively low surface speed of rotation with a high reciprocating speed of the laps across the gear face. The lap-spindle heads are adjustable to provide the correct amount of crossed-axis adjustment (lap angle minus gear angle). The machine is automatic in operation and the lapping cycle may be adjusted to meet requirements.

The Michigan three-lap type of machine not only accelerates

the lapping operation, but permits lapping more at some portion of the tooth and less at other portions. This, for example, is done in "crowning" or when the major bearing is to be at the center of the tooth. The lapping cycle of this machine is under automatic control. See also Gear-tooth Grinding.

Gear-Hobbing Machines. Gear-hobbing machines are commonly applied to the cutting of spur, helical, and worm gearing. In the practical application of the generating principle to gear-hobbing machines, the hob used has cutting teeth of the same cross-sectional shape as teeth of a rack of corresponding pitch, except for minor variations such, for example, as increasing the length of the hob teeth to provide for clearance at the bottom of the tooth spaces. As the hob teeth lie along a helical path (like a screw thread) the hob is set at an angle to align the teeth on the cutting side with the axis of the gear blank. When the hob is inclined an amount depending upon its helix angle the teeth on the cutting side represent a rack.

When a hobbing machine is in operation, the gear blank and hob revolve together, the ratio depending upon the number of teeth in the gear and the number of threads on the hob—that is, whether the hob has a single or a multiple thread. This rotation of the hob causes successive teeth to occupy positions corresponding to the teeth of a rack, assuming that the latter were in mesh with the revolving gear and moving tangentially. In conjunction with the rotary movement of the hob, the slide on which it is carried is given a feeding movement parallel to the axis of the gear blank.

Gear Planers of Templet Type. Large spur gears of coarse pitch may be cut either by planing on a templet or form-copying type of machine, by milling with a formed cutter, or by hobbing. Most gear manufacturers use the templet planer for the very large gears. One advantage of this type of machine is that simple, inexpensive tools are used, and this is very important, as often only one of these large gears is required, and the cost of making a formed cutter or hob would be prohibitive. Gear-cutting machines of the templet type are also used for cutting large spur, bevel, and herringbone gears; in fact, gear planers of this class are used invariably for cutting very large bevel gears. Some gear planers are designed for cutting spur gears exclusively, but there are also combination types which may be applied to either spur or bevel gears.

A characteristic feature of the templet planer is the templet or master former which serves to guide the planing tool, thus causing it to plane teeth having the correct shape or curvature. When the planer is at work, a slide or head which carries the tool is given a reciprocating motion, and as the tool feeds inward for

each stroke, the path it follows is controlled by the templet. The traversing movement of the tool-slide is derived from a crank on some gear planers, whereas others have a reversing screw. Still another method of traversing the head is by means of a rack and pinion, the latter being arranged to rotate in opposite directions.

Gear Shaper. The Fellows gear shaper is a machine of the generating type which operates with a shaping or planing action to generate gear teeth. The cutter has tooth outlines conforming to a gear of the same pitch as the ones being cut. This cutter is reciprocated vertically, and in starting to cut a gear it is first fed in to depth; then one gear tooth after another is formed as cutter and work slowly rotate together just as though two finished gears were in mesh. The gear blank is withdrawn from the cutter upon the return stroke to prevent dragging, the work-arbor being held by an apron actuated by a relieving mechanism. The gear teeth can be finished in one revolution of the gear blank, although a light finishing cut is often taken. In cutting transmission gears for automobiles, it is common practice to take a roughing cut followed by a light finishing cut. The machine may be arranged to take these two cuts automatically, but when gears are required on a large scale, it is generally considered preferable to use certain machines for roughing and others for finishing.

Gears, Non-Metallic. Non-metallic gears are used primarily where quietness of operation at high speed is the first consideration. Rawhide was the earliest material used for this class of gearing; later numerous other materials such as micarta, formica, condensite, fabrico, fabroil, and Egyptian fiber were introduced. These materials are used by many gear manufacturers when the gears are not subjected to severe stresses.

Gears, Ratios in Speed-Changing Mechanisms. See under Speed-Changing Mechanisms.

Gear Steels. Gear steels may be divided into two general classes—the plain carbon and the alloy steels. Alloy steels are used to some extent in the industrial field, but heat-treated plain carbon steels are far more common. The use of untreated alloy steels for gears is seldom, if ever, justified, and then, only when heat-treating facilities are lacking. The points to be considered in determining whether to use heat-treated plain carbon steels or heat-treated alloy steels are: Does the service condition or design require the superior characteristics of the alloy steels, or, if alloy steels are not required, will the advantages to be derived offset the additional cost? For most applications, plain carbon steels, heat-treated to obtain the best of their qualities for the service intended, are satisfactory and quite economical. The advantages

obtained from using heat-treated alloy steels in place of heat-treated plain carbon steels are as follows:

1. Increased surface hardness and depth of hardness penetration for the same carbon content and quench.
2. Ability to obtain the same surface hardness with a less drastic quench and, in the case of some of the alloys, a lower quenching temperature, thus giving less distortion.
3. Increased toughness, as indicated by the higher values of yield point, elongation, and reduction of area.
4. Finer grain size, with the resulting higher impact toughness and increased wear resistance.
5. In the case of some of the alloys, better machining qualities or the possibility of machining at higher hardnesses.

Gear Steels, Casehardening. Each of the two general classes of gear steels may be further subdivided as follows: (1) Casehardening steels; (2) full-hardening steels; and (3) steels that are heat-treated and drawn to a hardness that will permit machining. The first two—casehardening and full-hardening steels—are interchangeable for some kinds of service, and the choice is often a matter of personal opinion. Casehardening steels with their extremely hard, fine-grained (when properly treated) case and comparatively soft and ductile core are generally used when resistance to wear is desired. Casehardening alloy steels have a fairly tough core, but not as tough as that of the full-hardening steels. In order to realize the greatest benefits from the core properties, casehardened steels should be double-quenched. This is particularly true of the alloy steels, because the benefits derived from their use seldom justify the additional expense, unless the core is refined and toughened by a second quench. The penalty that must be paid for the additional refinement is increased distortion, which may be excessive if the shape or design is not all that it might be.

S A E Steels for Casehardening: These steels include carbon steel No. 1020, nickel steel No. 2315, nickel-chromium steel No. 3115, and nickel steel No. 2512. The steel identified as 2512 is No. 2515 with the carbon content held to 0.17 per cent max. No. 2512 has excellent core toughness and a minimum of distortion after quenching.

Gear Steels, "Full-Hardening." Full-hardening steels are used when great strength, high endurance limit, toughness, and resistance to shock are required. These qualities are governed by the kind of steel and treatment used. Fairly high surface hardnesses are obtainable in this group, though not so high as those of the casehardening steels. For that reason, the resistance to wear is not so great as might be obtained, but when wear re-

sistance combined with great strength and toughness is required, this type of steel is superior to the others. Full-hardening steels become distorted to some extent when hardened, the amount depending upon the steel and quenching medium used. For that reason, full-hardening steels are not suitable for high-speed gearing where noise is a factor, or for gearing where accuracy is of paramount importance, except, of course, in cases where grinding of the teeth is practicable. The medium and high-carbon percentages require an oil quench, but a water quench may be necessary for the lower carbon contents, in order to obtain the highest physical properties and hardness. The distortion, however, will be greater with the water quench.

S A E Full-Hardening Steels: The S A E steels include carbon steel No. 1045, nickel-chromium steel No. 3145, chromium-vanadium steel No. 6145, and molybdenum steel No. 4150.

Gear Steels, Heat-Treatment after Machining. When the grinding of gear teeth is not practicable and a high degree of accuracy is required, hardened steels may be drawn or tempered to a hardness that will permit the cutting of the teeth. This treatment gives a highly refined structure, great toughness, and, in spite of the low hardness, excellent wearing qualities. The lower strength is somewhat compensated for by the elimination of the increment loads due to the impacts which are caused by inaccuracies. When steels that have a low degree of hardness penetration from surface to core are treated in this manner, the design cannot be based on the physical properties corresponding to the hardness at the surface. Since the physical properties are determined by the hardness, the drop in hardness from surface to core will give lower physical properties at the root of the tooth, where the stress is greatest. The quenching medium may be either oil, water, or brine, depending on the steel used and hardness penetration desired. The amount of distortion, of course, is immaterial, because the machining is done after heat-treating.

S A E Steels for Heat-Treatment After Machining: These include carbon steel No. 1045, nickel-chromium steel No. 3140, and molybdenum steel No. 4130.

Gears, Types. See Bevel Gear; Bevel Gears, Gleason System; Friction Gearing; Helical Gears; Herringbone Gears; Internal Gears; Maag Gearing; Spur Gearing.

Gear Teeth. See Cycloidal Gear Teeth; also Involute Gear Teeth.

Gear Teeth Invention. The invention of gear teeth cannot be credited to any one man, as their development represents a gradual evolution from gearing of primitive form. Gears were known to Archimedes who lived 287-212 B.C., according to Ctesi-

bius of Alexandria in his "History of Mathematics." Ctesibius first applied gears to the clepsydrae (water clocks) about 150 B.C. The knowledge and use of toothed wheels by the Romans early in the Christian era is indicated by the fact that they are shown sculptured on the Column of Trajan in Rome. Leonardo da Vinci showed an appreciation of the use of gearing, many applications of it in connection with mechanisms devised for widely varying purposes being found in the sketches that form a part of his "Codice Atlantico." This work illustrates the use of worm-gearing, and suggests a choice of two forms of teeth, one of the buttress type and the other in shape much like present-day practice.

The Cycloidal Form: The earliest evidence we have of an investigation of the problem of uniform motion for toothed gearing and the successful solution of that problem, dates from the time of Olaf Roemer, the celebrated Danish astronomer, who, in the year 1674, proposed the epicycloidal form to obtain uniform motion in trains of gearing. In 1766 Charles E. L. Camus, in his treatise "Cours de Mathematique," dealt with gearing. This treatise fully describes the epicycloidal curve in such a way as to make it for the first time available to some extent for practical application, and points out its advantages as applied to gearing. Camus deals only with the epicycloidal form of tooth, and emphasizes its application to clock and watch work. Evidently Robert Willis, professor in the University of Cambridge, was the first to make a practical application of the epicycloidal curve so as to provide for an interchangeable series of gears. Willis gives credit to Camus for conceiving the idea of interchangeable gears, but claims for himself its first application.

The Involute Form: The involute tooth was suggested as a theory by early scientists and mathematicians, but it remained for Willis to present it in a practical form for use by the manufacturing public. Perhaps the earliest conception of the application of this form of teeth to gears was by Philippe de Lahire, a Frenchman, who considered it, in theory, equally suitable with the epicycloidal for tooth outlines. This was about 1695 and not long after Roemer had first demonstrated the epicycloidal form. The applicability of the involute had been further elucidated by Leonard Euler, a Swiss mathematician, born at Basel, 1707, who is credited by Willis with being the first to suggest it. Willis devised the Willis odontograph for laying out involute teeth.

Selection of Pressure Angle: A pressure angle of 14½ degrees was selected for three different reasons. First, because the sine of 14½ degrees is nearly ¼, making it convenient in calculation; second, because this angle coincided closely with the pressure angle resulting from the usual construction at that time of epicy-

cloidal gear teeth; third, because the sides of all worm threads formerly used inclined 14½ degrees, so that the straight-sided involute rack has the same angle as the 29-degree worm thread.

The Formed Cutter: The invention of the formed cutter by Joseph R. Brown in 1864 made possible the use of accurately cut gearing and proved to be an important element in the introduction of the interchangeable system of involute gears.

Gear-Tooth Caliper. A vernier gear tooth caliper is used to measure the *chordal* thickness of a gear tooth. This chordal thickness, which is slightly less than one-half the circular pitch, may be determined as follows: First divide 90 degrees by the number of teeth in the gear, and then find the sine of the angle thus obtained. Next, multiply this sine by the pitch diameter; the product equals the chordal thickness. Before measuring the chordal thickness, it is necessary to set the vertical scale of the vernier gear tooth caliper so that the caliper jaws come into contact with the sides of the tooth at the pitch circle. To determine this vertical adjustment or "corrected addendum," the cosine of the angle equal to 90 degrees divided by the number of teeth, is first subtracted from 1; this difference is then multiplied by the pitch radius of the gear and the product is added to the addendum of the tooth. This final result equals the corrected addendum or the dimension to which the vertical scale of the gear tooth caliper should be set.

Gear - Tooth Chamfering. The teeth of gears in speed-changing mechanisms of the sliding-gear type, may be chamfered or beveled at the ends to facilitate sliding the gears into mesh when changing speeds. The pointed ends of the chamfered teeth engage more readily with the spaces of a mating gear.

Gear-Tooth Crowning. The crowning operation as applied to gear teeth is for the purpose of making the chordal thickness at the center slightly greater than at the ends. In other words, a crowned tooth is slightly barrel-shaped to avoid objectionable end or edge contact such as might be caused by misalignment or errors in gear manufacture. The crowning prevents excessive loading at the ends and is intended to increase the actual strength and wear resistance. The chordal thickness of the tooth at the center or at some specified intermediate point, usually is about 0.001 inch greater than the end thickness. Crowning is done in conjunction with gear-tooth shaving or finishing. A machine developed for this crowning and shaving operation is equipped with a controlling cam which is adjusted to vary the amount of crown and may be arranged to generate teeth of the conventional form or without crown. The crowning process is sometimes called ***curve shaving.***

Gear-Tooth Curves. In developing or laying out the teeth or spur gearing, the idea is to form the teeth in such a way that the action of the gears will be like plain disks rolling together, the motion being transmitted smoothly and at a uniform rate. Similarly, bevel gearing is intended to reproduce the action of two frustums of cones rolling in contact with each other. There are various curves which might be applied to gear teeth in order to secure rotation between two gears having intermeshing teeth, but the *involute curve* is used almost universally because it has certain practical advantages which account for the fact that it has largely replaced the cycloidal curves formerly employed. See Involute Gear Teeth, Cycloidal Gear Teeth, and Gear-tooth Standards.

Gear-Tooth Grinding. Several types of machines for grinding gear teeth have been developed. These machines are used extensively for finishing hardened aircraft gears.

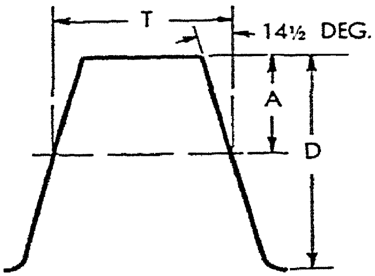
Single Wheel Method: One method of generating tooth curves by grinding is to use the flat face of a wheel which is perpendicular to the wheel axis and inclined from the vertical an amount equal to the pressure angle of the gear to be ground. In order to generate involute tooth curves, provision must be made for rolling the gear past the revolving grinding wheel, just as though an accurate gear were rolling along an accurate rack having the side of one tooth in the same position as the grinding face of the wheel.

Use of Two Grinding Wheels: A method of grinding two tooth surfaces at the same time consists in using two wheels which operate in different tooth spaces. The flat side of each wheel corresponds in location to the side of an imaginary rack tooth, and the generating action is the same as though the pitch circle of the gear were rolling along the pitch line of the rack, the motion being the same as with a single wheel. A master gear and rack mechanism is utilized to control the generating movement and to bring the gear into contact with the two grinding wheels.

Form-wheel Method: The formed-wheel method is based on the use of a grinding wheel having surfaces that are shaped to conform to the space between correctly formed gear teeth. This method is similar in principle to the use of formed cutters for cutting gear teeth, in that the shape of the grinding wheel is reproduced in the teeth.

Allowance: Just how must stock must be removed in grinding gear teeth to compensate for the greatest distortion that is likely to occur varies for different gears and frequently is affected by the method of heat-treatment. As a general rule, the removal of 0.003 to 0.005 inch from each tooth face is sufficient to correct all distortion, and in some cases, the removal of only 0.002 inch is sufficient. These allowances are based on the assumption that the

14½-Degree Full-depth Involute System

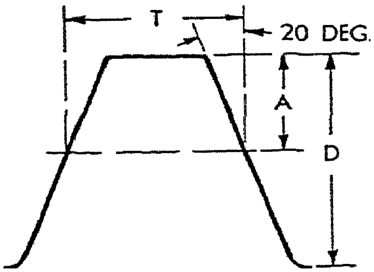


ADDENDUM A =
1 ÷ Diametral pitch
0.3183 × Circular pitch

TOTAL DEPTH D =
2.157 ÷ Diametral pitch
0.6866 × Circular pitch

BASIC THICKNESS T =
1.5708 ÷ Diametral pitch
0.5 × Circular pitch

20-Degree Full-depth Involute System

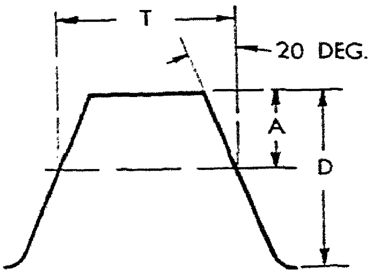


ADDENDUM A =
1 ÷ Diametral pitch
0.3183 × Circular pitch

TOTAL DEPTH D =
2.157 ÷ Diametral pitch
0.6866 × Circular pitch

BASIC THICKNESS T =
1.5708 ÷ Diametral pitch
0.5 × Circular pitch

20-Degree Stub Involute System

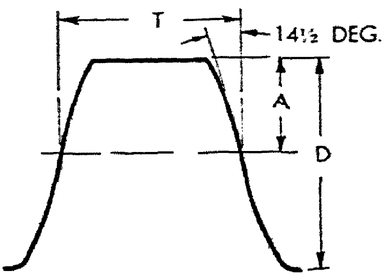


ADDENDUM A =
0.8 ÷ Diametral pitch
0.2546 × Circular pitch

TOTAL DEPTH D =
1.8 ÷ Diametral pitch
0.5729 × Circular pitch

BASIC THICKNESS T =
1.5708 ÷ Diametral pitch
0.5 × Circular pitch

14½-Degree Full-depth Composite System



ADDENDUM A =
1 ÷ Diametral pitch
0.3183 × Circular pitch

TOTAL DEPTH D =
2.157 ÷ Diametral pitch
0.6866 × Circular pitch

BASIC THICKNESS T =
1.5708 ÷ Diametral pitch
0.5 × Circular pitch

American Standard Basic Rack Tooth Forms

machine and cutters used for the preliminary cutting operation are of an approved type and in reasonably good condition.

Gear-Tooth Standards, American. There are four American standard spur-gear tooth forms, and these basic tooth standards are also applied to some extent in designing certain other types of gears. In establishing a gear-tooth standard, it is only necessary to give the proportions of the rack teeth because the rack is the basis or foundation of a standard system of interchangeable spur gears.

14 1/2-Degree Full-Depth Tooth: Standard tooth forms differ in regard to tooth depth for a given pitch and the angle or form of the basic rack tooth. The upper diagram (see accompanying chart) shows that the rack of a standard 14½-degree full-depth involute tooth. The total depth equals 2.157 divided by the diametral pitch and the other proportions are indicated by the formulas. This total depth is termed "full depth." The "stub tooth," referred to later, is somewhat shorter for a given pitch. This 14½-degree full-depth standard tooth form is very satisfactory, assuming that the tooth numbers are large enough to avoid excessive undercutting of the teeth. Undercutting will begin when the number of teeth is less than 32 and it may be excessive if the number is less than 22.

20-Degree Full-Depth Tooth: Practically the only difference between this 20-degree standard and the 14½-degree standard just referred to is in the pressure angle. (See second diagram.) The addendum, dedendum, and total depth are the same as for the 14½-degree full-depth tooth. This 20-degree rack tooth and gear teeth generated from it are wider at the base and consequently stronger than the 14½-degree standard as indicated by a comparison of the two basic rack diagrams. The larger pressure angle also reduces undercutting which begins when the number of teeth is less than 18 and may be excessive when the number is less than 14.

20-Degree Stub-Tooth Involute System: This standard differs from the 20-degree standard represented by the second diagram, in regard to the tooth depth, which equals 1.8 divided by the diametral pitch. The 20-degree pressure angle, in combination with a shorter tooth, strengthens the stub form and pinions with 12 and 13 teeth are only slightly under-cut. The length of contact between mating gears, however, is shortened, which tends to offset the increase in individual tooth strength and also tends toward greater noise when the gears are running, unless this tendency is offset by greater accuracy in cutting and mounting. Whether this noise tendency constitutes an objectionable feature may, for a given grade of gearing, depend upon the class of service. For example, noise which might be excessive in an automotive trans-

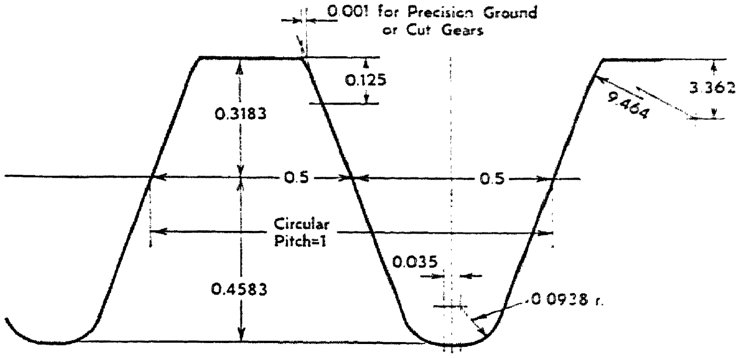
mission, would not be a factor in gearing applied to some other classes of machinery.

The 20-degree stub tooth is extensively used for automotive transmissions because relatively small gears are required and the maximum power-transmitting capacity for a given pitch or material is essential. For this class of service, however, very accurate gears are necessary and the mountings are designed to minimize noise. Helical forms of teeth are also utilized because they are conducive to smooth continuous action. The American Standard 20-degree stub tooth system is recommended by the American Gear Manufacturers' Association. Gears having this stub tooth may be used interchangeably with other stub-tooth systems and only the amount of clearance will be affected as the result of variations in tooth heights. See also Stub-Tooth Gears.

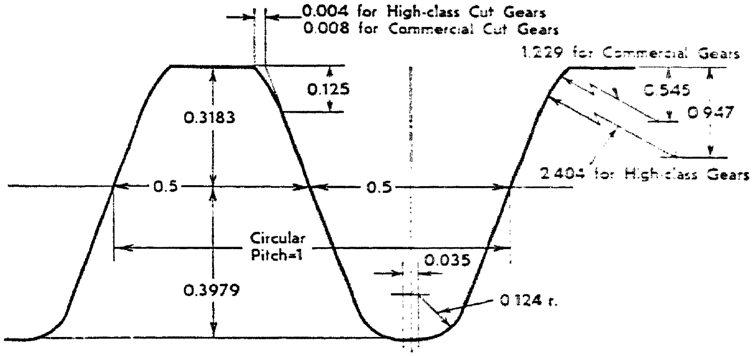
14½-Degree Composite System: This standard differs from the 14½-degree full-depth involute system in regard to the form of the basic rack teeth. The nominal pressure angle is the same and also the various formulas for determining tooth depth, addendum, dedendum, etc. The straight-sided or involute form of rack, however, is modified by introducing a cycloidal curve below the pitch line, and also one above it to make the tooth symmetrical as required for interchangeable gearing. Since it would be impracticable to produce in the shop a rack with cycloidal curves, or a cutter of this exact form, an approximate form of rack is used and meets practical requirements. The curves of this approximate rack are arcs having a radius equal to 3.750 divided by the diametral pitch. These curves are close approximations of the cycloidal curves on the theoretical rack. The 14½-degree composite tooth form was developed originally for use with the form milling process and gear teeth conforming to this standard generally are cut by form milling. They can, however, be produced readily on hobbing or other generating machines by making a hob or cutter of the basic rack form. If a hob is used, the relieving tool can be made to the form of the basic rack tooth. The line of tooth action is longer with the composite system than with the pure involute tooth form.

Gear-Tooth Standards, British. The British standard tooth form for spur gears is a 20-degree full-depth involute form. This same standard applies to single and double helical gears for connecting parallel shafts. For helical gears the tooth shape and proportions apply to a section at right angles to the helix, normal pitch being substituted for circular pitch. The standard specification includes the following classes:

Class A: Precision ground or cut gears suitable for peripheral speeds exceeding 2000 feet per minute.



Basic Rack Tooth Shape for Precision Ground or Cut Gears—20-degree Pressure Angle



Basic Rack Tooth Shape for High-Class or Commercial Cut Gears—20-degree Pressure Angle

Class B: High-class cut gears suitable for peripheral speeds between 750 and 3000 feet per minute.

Class C: Commercial cut gears suitable for peripheral speeds below 1200 feet per minute.

The range of speeds specified for the three classes permits considerable overlap. If the speed of any particular gear falls in either of two classes, it is implied that the lower class is suitable but the higher class may be selected to meet exceptionally severe conditions or to obtain a higher grade of work. This specification does not include traction gears, turbine or aviation gearing, or special applications.

Rack Tooth Shape: Basic rack tooth shape for unit circular pitch is shown by the accompanying illustrations. The upper drawing shows the basic rack for precision ground or cut gears (Class A) and the lower one, the basic rack for high-class and

commercial cut gears (Classes B and C). The pressure angle in each case is 20 degrees and the rack tooth has straight sides or the involute form except that a slight easing of the point is permissible. The amount of this easing or "tip relief" shall not exceed the following values as measured on the basic rack:

Class A: Precision ground or cut gears: 0.001 $\times$ circular pitch extending 0.125 $\times$ circular pitch in depth.

Class B: High-class cut gears: 0.004 $\times$ circular pitch extending 0.125 $\times$ circular pitch in depth.

Class C: Commercial cut gears: 0.008 $\times$ circular pitch extending 0.125 $\times$ circular pitch in depth.

The basic rack for Class A gears has the same addendum as the rack for Classes B and C, but the dedendum is greater. The shape of the space at the root of these basic rack teeth is approximately semi-circular. This bottom clearance space is a continuous curve and as nearly semi-circular in form as the tooth shape and system of cutting will permit. Although the increased depth of space due to the semi-circular clearance reduces the static strength, tests have shown that this form greatly increases the resistance to fatigue of hardened and heat-treated gears, and it is not considered detrimental to other types of gears made from iron, steel or bronze.

Pressure Angle: In establishing a single standard for general application to new work, the 20-degree full-depth tooth was recommended, although the committee fully realized that stub-tooth gearing and gearing with a pressure angle of 14½ degrees have been used successfully for many years and will, for certain purposes, continue to be used. This standard 20-degree pressure angle tooth possesses the desirable qualities of strength and ability to withstand wear, and, at the same time, is equal to other forms as regards quietness of running. Compared with the 14½-degree pressure angle, the strength at the root is considerably greater and undercutting in gears having small numbers of teeth is not so pronounced. The 20-degree full-depth tooth is approximately equal in strength to the 20-degree stub tooth, but has an advantage over the latter as regards wearing properties in having a longer arc of contact. Although the arc of contact is a little shorter as compared with the 14½-degree pressure angle, the relative radius of curvature of the tooth faces is greater, which more than compensates for the reduction in the length of the arc of contact.

Genelite. The material called "Genelite," is a bearing bronze, made synthetically. The admixture of finely divided graphite with the bronze is done in such a manner that it results in a uniform distribution throughout the mass in a volume proportion as high as 40 per cent. This uniform distribution is accomplished by

mixing graphite with the powdered oxides (copper, lead, and tin oxides) composing the bronze, in a sufficient quantity to reduce the oxides and leave the desired amount of graphite after the reduction is complete. The mixture is then put through a reduction process, being kept in the powdered form known as "Genelite powder," until the final steps. These consist of pressing the partially reduced powder in heavy steel molds under a high pressure as nearly as possible to the desired size and shape, and then giving it a final heat-treatment. Besides its use for bearings Genelite is also used for facing the rotating parts of valves used in systems handling caustic solutions. Among the properties claimed for this material are those of not sizing or sticking and of being somewhat self-lubricating. The material has the appearance of bronze and can be easily ground, but is not easily machined. It was developed in the research laboratory of the General Electric Co.

General-Purpose Motor. According to the National Electrical Manufacturers Association adopted standard, a *general-purpose motor* (except synchronous motor) is any motor of 200 horsepower or less and speeds higher than 450 revolutions per minute, having a continuous time rating, and designed, listed, or offered in standard ratings for use without restriction to a particular application.

A *general-purpose synchronous motor* is any motor rated 200 horsepower or less at 1.0 power factor or 150 horsepower or less at 0.8 power factor and speeds higher than 450 revolutions per minute, having a continuous time rating, and designed, listed, or offered in standard ratings for use without restriction to a particular application.

Generating Gear Teeth. See Gear Cutting by Generating Process.

Generator, Alternating-Current. An alternating-current generator, or alternator or synchronous generator, as it is also termed, is a machine that transforms mechanical power into electrical power. It has a magnetic field and an armature for delivering alternating currents in synchronism with the motion of the machine; that is, currents having a frequency strictly proportional to the speed of the machine. The instantaneous values of the electromotive forces (commonly written E.M.F.) and the currents are constantly changing from maximum positive to maximum negative, but the specified or effective value is equal to the square root of the average value of the square of the instantaneous values, which, for a true sine wave, is equal to the maximum value divided by $\sqrt{2}$. Almost all alternating-current generators of large capacity are of the revolving-field type, because the transmission of a current under high voltage through collector

rings and brushes, as required in the revolving-armature type, causes break-down troubles, as it is difficult to insulate the rings and brushes effectively. The stationary-armature winding, however, may be easily insulated, as it is not subjected to the mechanical stresses of the revolving-armature type and the crumbling from vibration imparted by a revolving member.

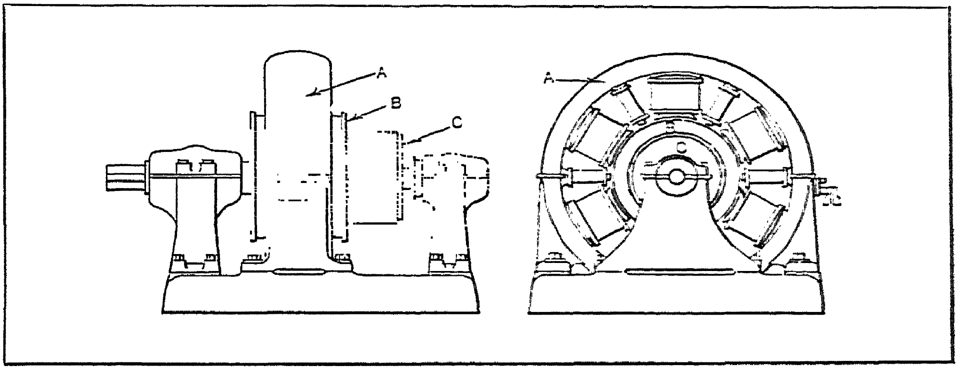
Alternating-current generators may be single-, two-, or three-phase machines, depending upon whether they generate a single alternating electromotive force, or two or more electromotive forces that differ in phase by a fixed amount; in the latter case they are also known as "polyphase generators." Three-phase generators are used almost exclusively on account of the saving that may be obtained. They are about two-thirds as heavy and as expensive as a single phase generator of the same rating. With the same line voltage and loss, the three-phase system will save about 25 per cent in the weight of the line conductors, as compared with either of the other systems—besides the reduced cost of line material and labor. Hence, when two-phase generators are required, it is usually for additions to an old system. The universal trade terms for alternating-current generators are: *ASB* for single-phase generators; *AQB* for two- or quarter-phase generators; and *ATB* for three-phase generators. In each case, *B* means revolving field.

Generator, Direct- and Alternating-Current. Both direct- and alternating-current electricity can be produced by a generator developed for use primarily with welding equipment. Because of the universal alternating or direct current feature, spot or tack, semi-arc and nickel-flash welding operations can be performed with alternating current, and if it is desired to perform other operations for which it is preferable to use direct current, this kind of current can be obtained immediately. The full capacity of the equipment can be obtained with both currents. As the same armature winding serves for both currents, no extra space is required for the winding as compared with that necessary in a generator delivering only one of the currents. The only extra parts required are two collector rings for the alternating current. The main feature of the generator is that either the alternating- or direct-current leads can be short-circuited right at the collector rings or the commutator without injury; the generator voltage simply dies down to a value that holds the current constant, and there is no injury of the generators while in this condition. With the release of the short circuit, the normal voltage is immediately obtained. The generator has a power take-off at both ends for driving equipment or machines.

Generator, Direct-Current. A direct-current generator is a machine that transforms mechanical power into electrical power,

giving a current that is unidirectional or non-pulsating. It is constructed on the principle that a conductor moved across a magnetic field, in a direction at right angles to the lines of force or magnetic flux, will induce an electromotive force in that conductor. Direct-current generators are used for light, power, and railway service; for all purposes there is a close similarity in the electrical and mechanical design, the main difference being in the use of larger commutators for the first two, due to the lower voltage and greater amount of current to be handled.

The direct-current generator consists essentially of two distinct elements, a stationary field *A*, and a rotating armature *B* (see illustration). The field is composed of electromagnets of alternate polarity arranged in a circle, as shown, while the armature consists of a system of conductors arranged on an iron drum and operating in the magnetic field set up by the electromagnets. As



Direct-current Generator

the conductors are acted upon alternately by north and south poles, the current generated in the conductors flows first in one direction and then in the opposite direction. To secure a constant flow of current in one direction, therefore, a device *C*, known as a *commutator*, is used to rectify the alternating, or pulsating, currents as they are generated in the armature conductors. This device, which constitutes a third essential element in a direct-current generator, consists of a number of copper segments or bars insulated from one another and connected to appropriate points of the armature winding. The potential, or voltage, of the bars will have a constantly varying value, which corresponds to the fluctuating potential induced in the conductors to which they are connected, as these conductors pass the pole pieces. The points of maximum potential on the commutator will, therefore, be equal to the number of field poles, as a conductor generates its maxi-

mum voltage while passing through the densest part of the pole flux; and although these maximum points are shifting rapidly from bar to bar around the commutator, their position relative to the stationary poles is fixed. This fact permits the collection of a constant-voltage direct current by means of contact brushes arranged to bear upon the commutator at equally-spaced points around its circumference.

Direct-current generators may be classified according to the manner in which they are "excited," that is, the manner in which the electromagnets are energized; they may be "separately excited," or "self-excited." When the generators are separately excited, the current for the field winding is taken from an outside source; when they are self-excited, it is drawn from the armature of the machine itself. Self-excitation is the form most commonly used on account of its simplicity, although the field current is then dependent upon the brush potential. When it is desirable to maintain a field strength independent of the brush potential, separate excitation should be used. Self-excited, direct-current generators may also be classified according to the manner in which the field windings are arranged; such as series-wound, shunt-wound, and compound-wound. See Series-wound Generator; Shunt-wound Generator; and Compound-wound Generator.

Generator, Double-Current. A double-current generator is a machine driven by mechanical power and producing direct current as well as alternating current from the same armature winding, which is connected to both commutator and collector rings. This type of machine is occasionally used for testing purposes.

Generator, Inductor Type. The inductor generator is a synchronous type in which both the field and armature windings are stationary and only the pole pieces revolve. Due to the varying reluctance of the magnetic circuit, caused by the revolving poles, the flux linked with the armature coils will vary periodically, and induce an alternating electromotive force in the armature winding. This type was extensively used before the introduction of the revolving-field alternator, which has proved to be far superior to the inductor alternator.

Generator Rating. According to the American Standard for Rotating Electrical Machinery, the rating of a generator shall consist of the output together with any other characteristics such as speed, voltage, frequency, and current, assigned to it by the manufacturer. The output for direct-current generators is usually given in watts or kilowatts (kw) available at the terminals at a specified speed and voltage, and for alternating-current generators in kilovolt-amperes (kva) available at the terminals at a specified speed, frequency, voltage, and power factor.

The various kinds of rating recognized are:

Continuous Rating: This rating defines the load which can be carried for an unrestricted period without causing any of the established standard limitations to be exceeded.

Short-Time Rating: This rating defines the load which can be carried for a specified time (5, 10, 15, 30, 60 or 120 minutes) without causing any of the established standard limitations to be exceeded.

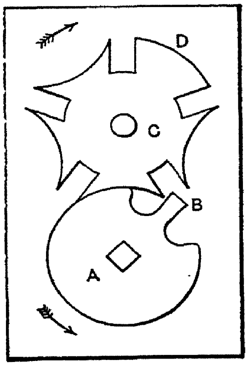
Nominal Rating: This rating defines the constant load which, having been carried without causing further measurable increase in temperature rise, may be increased 50 per cent in amperes at a specified voltage for two hours without causing any of the established standard limitations for nominally rated machines to be exceeded.

Continuous with Two-Hour 25 per Cent Overload Rating: This rating defines the load which can be carried continuously, immediately followed by a 25 per cent overload for two hours, without causing any of the established standard limitations to be exceeded.

The permissible temperature rise of the armature and field windings, the cores and mechanical parts adjacent to or in contact with the insulation, and the commutators and collector rings, above the temperature of the cooling medium (ambient temperature of the air in many cases) is also outlined in this American Standard.

Generator Winding. See Compound-wound Generator; Series-wound Generator; Shunt-wound Generator.

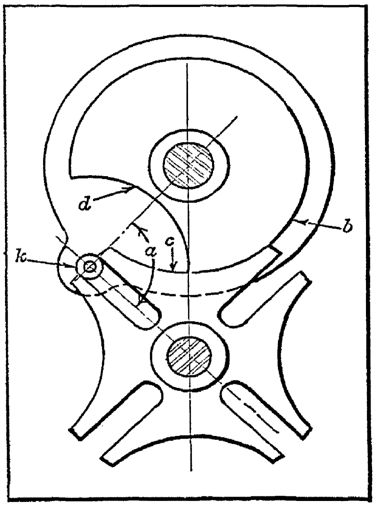
Geneva Stop. The Geneva stop is a simple form of mechanism applied to watches, etc., to prevent winding the main spring too tightly. The principle of the mechanism is illustrated by the diagram. A disk *A* has one projecting tooth *B*, and is fixed upon the spindle of the barrel or casing containing the main spring. Another disk *C* provided with notches that are engaged by tooth *B* is rotated through part of a revolution each time tooth *B* makes one complete turn and engages one of the notches or tooth spaces. As that part of disk *C* between the notches is curved to the same radius as disk *A*, disk *C* is locked and prevented from rotating during the time that the tooth *B* is out of engagement. When disk *A* is turned, the intermittent motion of disk *C* continues until the convex portion *D* comes around into engagement with disk *A*, thus preventing any further rotation. With this ar-



Geneva Stop

rangement, the number of revolutions for disk *A* can be positively regulated so that over-winding of the spring is avoided. When the winding action has ceased, the disks will return to their original positions as the mechanism of the watch is driven by the spring and runs down. The principle of the Geneva stop has been applied to various classes of machinery in order to obtain the intermittent motion resulting from this form of mechanism.

Geneva Wheel. The general type of intermittent gearing shown in the illustration is commonly known as a "Geneva wheel," because of the similarity to the well-known Geneva stop. Geneva wheels are frequently used on machine tools for indexing or rotating some part of the machine through a fractional part of a revolution. The driven wheel shown in the illustration has four radial slots located 90 degrees apart, and the driver carries a roller *k* which engages one of these slots each time it makes a revolution, thus turning the driven wheel one-quarter revolution. The concentric surface *b* engages the concave surface *c* between each pair of slots before the driving roller is disengaged from the driven wheel, which prevents the latter from rotating while the roller is moving around to engage the next successive slot. The circular boss *b* on the driver is cut away at *d* to provide a clearance space for the projecting arms of the driven wheel. In designing gearing of the general type illustrated, it is advisable to so proportion the driving and driven members that the angle *a* will be approximately 90 degrees. The radial slots in the driven part will then be tangent to the circular path of the driving roller at the time the roller enters and leaves the slot. When the gearing is designed in this way, the driven wheel is started gradually from a state of rest and the motion is also gradually checked.



Geneva Wheel

Geometrical Progression. A geometrical progression is a series in which each term is derived by multiplying the preceding term by a constant multiplier called the *ratio*. When the ratio is greater than 1, the progression is increasing; when smaller than 1, it is decreasing. Thus, 2, 6, 18, 54, etc., is an increasing geometrical progression with a ratio of 3, while 24, 12, 6, etc., is a decreasing progression with a ratio of ½.

Geometric Lathe. The machine known as a "geometric lathe" is a special machine designed for engraving intricate designs on

fine dies or plates. The elaborate scroll work found on paper money is an example of the engraving done by the geometric lathe. While this machine is known as a "lathe," is is, in reality, a highly specialized type of engraving machine. The geometric lathe was invented by Charles W. Dickinson, and was first used for engraving bank-note plates in 1862. This machine produces an almost endless variety of geometric figures by utilizing various combinations of gears, cams, and eccentrics. By varying the patterns for treasury notes, postage stamps, revenue stamps, etc., counterfeiting is made difficult. Moreover, the operation of one of these machines requires an expert mathematician. The lathe has a number of superimposed flat plates which are actuated by cams and gearing, and the die to be engraved is held by the top platen or chuck. The hardened steel tool which is sometimes pointed with a diamond is fastened in a stationary position, and the die is given the various movements necessary to produce each pattern.

Georgia Corundum. This is a natural abrasive containing about 77 per cent of crystalline alumina, which constitutes the cutting material of the abrasive. It is mined in Georgia; hence the name.

German Silver. German silver, also known as "nickel silver," is an alloy of copper, nickel, and zinc, the best quality consisting of 50 per cent of copper, 25 per cent of nickel, and 25 per cent of zinc. This quality, however, is the most difficult to work, but takes a fine polish and is frequently used for tableware to imitate silver. When the proportion of copper is somewhat higher, the alloy is suitable for rolling and for drawing into wire. German silver is known under probably a greater number of names than any other alloy. In addition to the name "nickel-silver," it is also known as "Chinese white silver," or "packfong," "white copper," "silveroid," "Nevada silver," and "electrum." German silver can be hammered, rolled, stamped, and drawn. At the same time, it possesses the properties of being hard, tough, and not easily corroded, but, when exposed to the air, it tarnishes, becoming slightly yellow. At a heat above dull red, it becomes very brittle. German silver can be readily soldered. The usual composition of German silver solder is: Copper, 47 per cent; nickel, 11 per cent; and zinc, 42 per cent.

Gherkin's Latch. This is a mechanism used for automatically returning a machine member to the starting point or central position after it has been thrown out of this position by the action of the machine.

Gibs. A gib (also known as an adjusting or take-up strip) may be defined as a wedge or adjusting shoe the object of which

is to insure a proper sliding fit between two machine parts, and to make possible the taking up of the wear after the proper adjustment has been lost through continued service. Briefly, therefore, the function of the gib may be said to be to prevent slackness between the slide and its slide-way, and to compensate for wear. Gibs are used extensively on various classes of machine tools. Gibs may be divided into three main groups, according to the mode of "setting-up" or adjusting. These groups include (1) gibs forced laterally by screws acting at right angles to the axis of the slide; (2) angular gibs pulled or forced sideways so as to have a wedge action between the slide and the slide-way; (3) gibs tapered longitudinally and forced in that direction, thus having a wedge action.

Gibsiloy. Eight grades of nickel-silver, silver-nickel-tungsten, silver-nickel-molybdenum and silver-nickel-cadmium powdered-metal compositions which can be produced in button, wire, strip, or rod form. Can be headed into rivets or buttons for electrical contacts or coined to any shape required.

Gilbert. The gilbert is a unit of magnetomotive force, and is the amount of magnetomotive force that can be produced by a coil of $10 \div 4\pi$ ampere-turns, or 0.7958 ampere-turn. The magnetomotive force of a coil in gilberts equals 1.2566 times the ampere-turns. The abbreviation used to designate magnetomotive force is mmf.

Ginsaw File. Ginsaw files are of knife shape and single-cut. This type has been supplanted, to a considerable extent, by the three-square ginsaw file, which is made either tapering or blunt of hand-saw slim steel, and is used for filing cotton ginsaws.

Giolitti Process. This is a method for carburizing work to be casehardened by packing the work with wood charcoal in a cylinder, heating the work to a carburizing temperature, and then injecting a current of carbon dioxide into the cylinder. With the use of this process, a more rapid penetration of the carbon at the surface of the work can be obtained than with an ordinary solid carburizing mixture.

Girder. A beam of wood or iron, which is supported at each end upon walls or piers, and which supports a superstructure or load, such as a floor, a wall, or the roadway of a bridge, is known as a *girder*. When a girder is composed of upper and lower horizontal members united by vertical and diagonal bars, the girder is known as a *lattice* girder. When built up from steel plates and angles into compound shapes, forming I-beams or T-beams, the girder is commonly known as a *plate* girder. If built up from plates and angle irons to form a rectangular cross-section, the

girder is known as a *box* girder. All girders, however, in their mechanical sense are *beams.*

Glass Cutting. Sometimes it is necessary to cut plate glass so as to leave the edges smooth and straight. If this work is attempted with the aid of a diamond glass cutter and rule, the glass will break with a ragged edge. A method of overcoming this difficulty, which has been used in cutting plate glass as thick as ½ inch and with excellent results, is as follows: First obtain a good diamond glass cutter, and with this tool scratch the glass along the line on which it is to be cut, using any good straight-edge to guide the diamond. In this connection it may be mentioned that the deeper the cut the more uniform the surfaces of the cut edge will be. After laying the glass on a cold surface with the cut side up, for which purpose the surface plate is very satisfactory, an iron or steel rod about ¼ inch in diameter is heated to a dull red. This rod is then laid along the line scratched by the diamond point and pressed lightly against the glass. When held in position for from one to four minutes—depending on the thickness of the glass—it will be found that the glass will crack along the line, leaving a uniform surface.

Glass Drilling. There are several methods of drilling holes in glass. For holes of medium and large size, use brass or copper tubing, having an outside diameter equal to the size of hole required. Revolve the tube at a peripheral speed of about 100 feet per minute, and use carborundum (80 to 100 grit) and light machine oil between the end of the pipe and the glass. Insert the abrasive under the drill with a thin piece of soft wood so as to avoid scratching the glass. The glass should be supported by a felt or rubber cushion, not much larger than the hole to be drilled. If practicable, it is well to drill about halfway through and then turn the glass over and drill down to meet the first cut. Any fin that may be left in the hole can be removed with a round second-cut file wet with turpentine. For comparatively small holes, a solid drill is often used. Use steel rod or an old three-cornered file, grinding the end to a long tapering triangular shaped point. Grip the drill in a chuck and rotate rapidly. Use a mixture of turpentine and camphor as a lubricant. Holes up to ½ inch in diameter can be drilled in glass with a flat drill which has been hardened in sulphurous acid, a mixture of turpentine and camphor being used as a lubricant. Ordinary twist drills are also used for drilling glass, the turpentine and camphor mixture being used as a lubricant. The glass is drilled about halfway through and then turned over so that the remaining depth may be drilled from the opposite side.

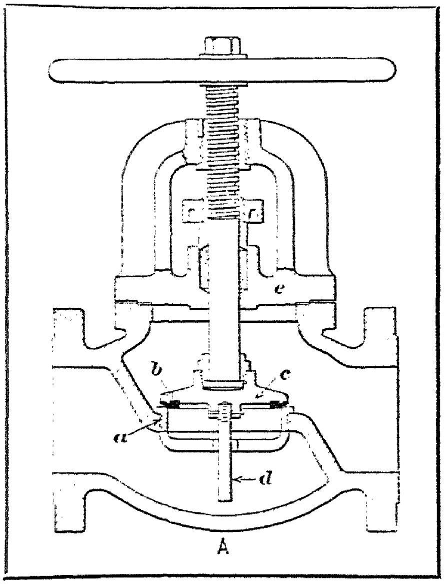
Glass Graduating. See Graduating on Glass.

Glazed Grinding Wheel. A wheel is "glazed" when the cutting particles have become dull or worn down even with the bond, which latter is so hard that the abrasive grains are not dislodged when too dull to cut effectively. Glazing may indicate either that the wheel is too hard for the work, or that the wheel speed is too high. The remedy, then, for glazing is to decrease the speed or use a softer wheel.

Glazing. The roughing operation, preparatory to finishing knife blades and cutlery, is performed with solid grinding wheels and the polishing is known as fine or blue glazing, but these terms are never used when referring to the polishing of hardware parts.

Gleason System of Bevel Gears. See Bevel Gears, Gleason System.

Globe Valves. One of the heavier types of globe valves is shown by the sectional view. This type of valve has a metal seat formed by the screw bushing *a*, against which the ring *b*, which forms a portion of the disk *c*, is forced by the raising or lowering of the stem to which the handwheel is attached. In this particular valve, the bronze bushing is provided with a guide through which a pilot *d* on the end of the valve-stem passes in order to assist keeping the moving parts in their correct positions. The stem of the valve passes through the bonnet *e* and is made tight by packing it with suitable material. In smaller valves of the globe type, a metal seat is not always employed, a ring of fiber or vulcanized rubber composition being used instead. A fiber ring of this kind can be easily replaced, so that the valve can be kept tight without trouble. The smaller valves are also made with metal seats so constructed that they can be readily re-ground to make the seat perfectly tight. Valves which have this provision are generally termed *re-grinding valves.* The screw on the valve-stem is generally of coarse pitch, and is sometimes a multiple screw, so as to permit opening the valve quickly. Valves of this kind are frequently made in angle form in order to take the place of elbows in the piping. There is a difference of opinion regard-

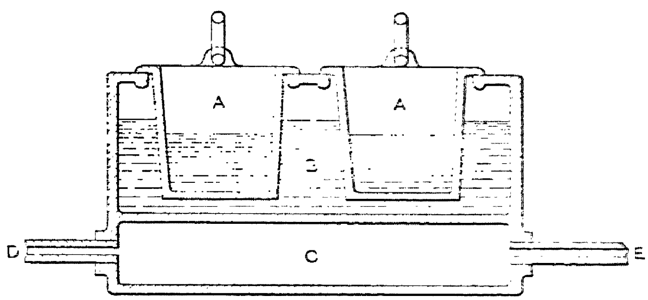


Globe Valve

ing which should be the pressure side of the valve. Many prefer to so connect the valves that the pressure is against the under side of the disk, as with this arrangement the stem of the valve can be readily packed when the valve is closed. When the pressure is on the top side of the disk, however, there is an advantage in that the thrust is against the valve-seat and not against the threads of the valve-stem.

Globoid Gearing. See Hindley Worm-gearing.

Glucinum. Glucinum is an alternative name used for the chemical element *beryllium;* the symbol is Gl, or sometimes G. The name "beryllium" has been used for many years, but recently the original name "glucinum" has been adopted by chemists, and both names are used to some extent, at the present time. For the properties of the element, see Beryllium.



Steam Glue Heater

Glue Heaters. Glue is always heated or boiled in a double boiler to prevent overheating and burning. The glue is placed in a pot that fits into a vessel containing water. The water in the outer vessel is heated either by an open flame, an electric current, or by steam. A sectional view of a simple steam glue heater is shown. The receptacles *A* are for holding the glue; *B* is the water container, and *C* is the steam jacket. The live steam enters at *D,* passes through the jacket and out at *E.* The flow of steam is controlled by a globe valve at the inlet.

Glues for Wood. The glues that are adapted for gluing wood, according to a report of the Forest Products Laboratory, U. S. Forest Service, Madison, Wis., may be conveniently divided into five classes as follows:

1. Animal glues, which are made from the hides, hoofs, horns, bones, and fleshings of animals, mostly cattle. These glues come in dry form, and must be mixed with water and melted.

2. Casein glues, which are made from casein, lime, and certain other chemical ingredients. They are commonly sold in prepared form, requiring only the addition of water, but may be mixed by the addition of the separate materials to the water.

3. Vegetable glues, which are made from starch, usually cassava starch, and sold in powdered form. They may be mixed cold with water and alkali, but heat is commonly used in their preparation.

4. Blood-albumin glues, which are made from soluble blood albumin, a product recovered from the blood of animals. These glues must be mixed just before use, since they deteriorate rapidly on standing.

5. Liquid glues, which are commonly made from the heads, skins, bones, and swimming bladders of fish. Some liquid glues are made from animal glue and from other materials. They come in prepared form ready for immediate use.

Animal Glue: Animal glue, frequently referred to as "hot glue," is familiar to all woodworkers. The principal desirable properties of animal glue are its great strength and reliability in the higher grades, its free-flowing consistency, and the fact that it does not stain wood. So far no glue has been found to be as suitable as animal glue for handspreading on irregular shaped joints. The price of animal glue is the chief factor that limits its use. The fact that it is not highly water-resistant is occasionally a drawback.

Casein Glue: Casein glue has sufficient strength for either veneer or joint work. It is used cold, and when properly mixed it can be spread with a brush. The property most featured is its high water-resistance, which makes it suitable for gluing articles to be used under moist conditions. Not all casein glues are water-resistant, however; there are some on the market which are made to compete with vegetable glue, and for which no great water-resistance is claimed. Among the disadvantages of casein glues are their tendency to stain thin veneer and the relatively short working life of some kinds. It is claimed that this trouble has been overcome to a certain extent in some glues. They are somewhat harder on tools than animal and vegetable glues.

Vegetable Glue: Vegetable glues have found wide use because they are cheap, can be used cold, and remain in good working condition free from decomposition for many days. They are extremely viscous, and it is not practicable to spread them by hand. Their lack of water-resistance and the fact that they usually cause staining in thin fancy veneer are factors limiting their use. They set relatively slowly, and for this reason are not so well adapted for joint work.

Glue: Blood-albumin glue has shown notably

high resistance to moisture, especially in the boiling test. This makes it particularly suitable for gluing plywood which is later to be softened in hot water and molded. The production of molded plywood articles has been very limited, but it offers a good field for future development. In the past the chief drawback to the use of blood glues has been the necessity for hot-pressing, but tests have shown that a highly water-resistant blood glue may be developed which can be cold-pressed successfully.

Liquid Glue: Liquid glues are, in general, similar in properties to animal glue. Some brands are quite equal in strength to good joint glues, but other brands are very weak and unreliable. Their great advantage is that they come in prepared form, ready for immediate use. This makes them particularly suitable for patch work and small gluing jobs. The factors that limit their use are their high price, their lack of water-resistance, and the difficulty in distinguishing between good and poor brands.

Veneer and Joint Glues: Generally speaking, present vegetable and blood-albumin glues are veneer glues, while animal and casein glues are used both as veneer and as joint glues. As between animal and casein glue for joint work, if freedom from staining is important, animal glue is preferable; if water-resistance is of importance, then a casein glue should be selected. Because of the necessity of heat in the preparation and use of animal glue, the casein cold glue will probably be favored if both glues are otherwise equally well adapted.

Glues Used in Polishing. There are three kinds of glue, namely, bone, hide stock, and fish glue. Hide stock glue is most generally used in the polishing industry. It is made from the skins of cattle, rabbits, and other animals. Glues are often blended; for example, a sheep stock and goat stock glue make an exceptionally strong holding medium, and, when mixed with ox fleshings, form a glue which has more strength than a glue made entirely from rabbit or some other similar stock. The cheaper grades of glue are usually mixtures of bone and hide glues.

Gluing Practice. The following information on gluing practice is based upon a report of the Forest Products Laboratory, United States Forest Service, Madison, Wis.

Weakness in glued joints may be caused (1) by allowing the glue to become too cold before applying pressure; (2) by using glue that is too thin and is squeezed out of the joint; or (3) by allowing the glue to dry too much before applying pressure. These three mistakes are the most common ones in gluing practice, and they are known as the "chilled joint," the "starved joint," and the "dried joint," respectively.

Strong joints may be obtained by changing either pressure, assembly time, or temperature, these being the three most im-

portant factors in the gluing operation when animal glue is used. Thus a good joint can be made from chilled glue by increasing the pressure, or the glue may be kept from becoming chilled and a good joint obtained if either the assembly time is decreased or the room temperature increased. If the glue is thin, starved joints may be avoided by decreasing the pressure, although such practice is not always recommended. Better average results are obtained if the consistency of a thin glue is increased either by increasing the assembly time or by decreasing the room temperature.

No amount of pressure will produce a good joint from dried glue, but by decreasing either the assembly time or the temperature to which the wood is subjected, a good joint can be made before the glue has dried out. Assembly time, room temperature, and wood temperature are chief among the factors affecting the consistency of an animal glue at the moment pressure is applied. Pressure then must be adjusted to suit the consistency of the glue, the thicker mixture requiring the greater pressure.

Glycerine Anti-Freezing Mixtures. See Anti-freezing mixtures.

Glycerine in Hydraulic Machinery. Glycerine has been used extensively in hydraulic presses and similar machinery because it acts to a certain extent as a lubricant, preserves the flexibility of cup leathers, has a high viscosity which makes it less likely to leak through fine pores in castings and defects in joints, and, finally, freezes at a very low temperature. It is also found that in many instances glycerine acts as a protection against corrosion of metallic surfaces. There are, however, other instances where apparently it either induces or accelerates corrosion. From an extensive investigation it would appear that whenever two metals of different electrical potential are employed in hydraulic apparatus with glycerine as the working fluid, the metal that constitutes the negative pole of the electric couple is always the one attacked. The conclusion is that in hydraulic or hydro-pneumatic apparatus employing glycerine as a working fluid, the parts should be so selected that contact of two different metals in the presence of the glycerine is always avoided.

Glycoseal. A flexible, leakproof, and non-cracking compound that can be used on rubber as well as on metals. As it will not harden, joints once formed can be broken readily without damage to fittings. Useful as a sealing compound for joints in pipes and containers carrying propane, pentane, butene, benzol, gasoline, naphtha, grease, and oils of all types.

Gold. Gold is the most malleable of all metals and is also extremely ductile. It may be beaten into leaves thin enough to

transmit a greenish light, and one grain of gold has been drawn into wire 500 feet in length. One of the most remarkable properties of gold is that it is permanent in both moist and dry air at all temperatures, and that it is insoluble in all acids except in aqua regia (a mixture of hydrochloric and nitric acids) which will dissolve it. Chlorine and solutions that generate chlorine will dissolve gold. Pure gold is rarely used in the arts or industries, because of its softness, it being nearly as soft as lead and much softer than pure silver; it is, therefore, generally alloyed with either copper or silver. Gold coins and gold ornaments are always made of alloys of gold and copper, or cold, copper, and silver. The coins of the United States are composed of 9 parts of gold and 1 part of copper. The specific gravity of gold, when cast, varies from 18.3 to 19.35, but the specific gravity of pure gold obtained by precipitation may be anywhere from 19.55 to 20.7. Generally, the specific gravity of commercial gold is given as 19.3. The melting point of gold is 1063 degrees C. (1945 degrees F.). As a conductor of electricity, gold ranks next to silver and copper. Its electrical conductivity is equal to 76.7 (silver = 100).

Gold Amalgam. Alloys formed by mercury and other metals are known as *amalgams*. Gold amalgam is an alloy of gold and mercury. It is used in gilding.

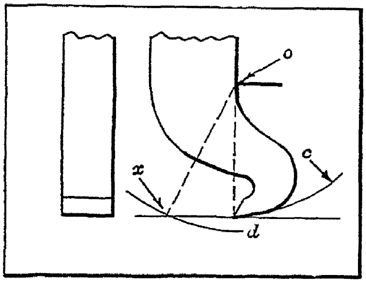
Gold, Mannheim. See Mannheim Gold.

Gold-Plating. Gold is universally plated from a solution of potassium gold cyanide, $KAuC_2N_2$, held in solution by potassium cyanide. The appearance of the deposited gold depends upon the temperature of the bath. A hot bath gives deposits of greater density and uniformity, and richer tones. Any other metal than copper must be copper-plated before gilding. The following bath is suitable for cold gilding: 54 grains of gold in the form of fulminating gold, from 0.35 to 0.5 ounce of 98-per-cent potassium cyanide, and 1 quart of water. Fulminating gold is prepared by adding ammonia to a solution of gold chloride. The fulminating gold is precipitated, filtered, and washed, and then dissolved in potassium cyanide, while still moist; if dried, it is highly explosive. Too much potassium cyanide causes the gilding to be pale. The following bath is suitable for hot gilding: 15.4 grains of gold in the form of fulminating gold; 77 grains of 98-per-cent potassium cyanide; and 1 quart of water. The temperature is from 158 to 176 degrees F. The current density used in gold-plating is from 0.93 to 1.4 ampere per square foot, at from 1 to 3 volts; the anodes are of fine gold. When very large objects are to be gilded, anodes of corresponding dimensions are required in order to insure a uniform current density. As it would be too expensive to use large gold plates, carbon may be substituted.

When gold-plating the insides of silver-plated utensils, the gold solution is poured into the vessel, and a gold anode suspended in the center from the positive pole of the generator; the negative is attached to the article itself. Pewter vessels are first copper-plated before undergoing the gilding or silvering process. During the operation of plating, it improves the solidity of the deposition to scratch-brush frequently, which also prevents the work turning to a dead brown-black. Red gilding is produced by the addition to the bath of copper cyanide in small amounts until the proper color is obtained. Green gilding is produced by the addition of silver cyanide. See also Electroplating.

Goniometer. The goniometer is an instrument used for measuring the angles of crystals. There are two kinds of goniometers, the *contact* goniometer and the *reflecting* goniometer. The first type is somewhat similar to the simplest type of draftsman's protractor, except that it is provided with an arm or rule pivoted at the center of the graduated semi-circle. The reflecting goniometer is an instrument of great precision, and is always used for accurate measurements of angles, when small crystals with bright faces are available. Several forms of this instrument have been devised, all being based upon the reflection of the light from the crystal faces.

Goose-Neck Tool. The peculiarly-shaped tool shown by the front and side views of the accompanying diagram, is especially adapted to finishing cast-iron surfaces. This type is known as the "goose-neck," because of its shape, and it is intended to eliminate chattering and the tendency which a regular finishing tool has of gouging into the work. By referring to the side view which represent this type of tool applied to a planer, it will be seen that the cutting edge is on a line with the back of the tool shank, so that any backward spring of the tool while taking a cut would cause the cutting edge to move along on arc *c* or away from the work. When the cutting edge is in advance at some point *x*, as with a regular tool, it will move along an arc *d*, if the strain of the cut causes any springing action, and the cutting edge will gouge in below the finished surface. Ordinarily, the tool and the parts of the planer which support it are rigid enough to prevent such a movement, so that the goose-neck tool is not generally used.



Goose-neck Planer Tool

Gordon's Formulas. These formulas were developed for the calculation of the strength of columns. They are also known as Rankine's formulas, which see.

Governors, Engine. The power developed by an engine may be changed either by varying the initial pressure or the point of cut-off. Governors which maintain a constant speed under variable loads by changing the initial pressure are called *throttling governors.* This form is uneconomical in the use of steam and is confined to the cheaper and less efficient types of engines, or where the cost of fuel is not of great importance. For high-speed engines employing a positive valve-gear, the shaft governor is commonly used. This operates by shifting the position of the eccentric upon the main shaft in such a manner as to produce the desired changes in the point of cut-off. Governors of this type act in two ways: Either by rotating the eccentric upon the shaft so as to change the angle of advance, or by swinging it in such a manner as to increase or diminish the throw, and thus change the travel of the valve. The first method not only changes the cut-off, but all other events of the stroke, if the governor is arranged to act upon the main valve, and, for this reason, it is confined chiefly to valves of the Meyer type having a riding cut-off. The swinging eccentric can be so pivoted that it will increase or decrease the travel of the valve, thereby changing the cut-off, while the lead may be increased or decreased at will, according to the design.

Governors, Inertia and Centrifugal. When the regulation of steam engine speed is automatically controlled, many of the governors used depend for their action upon the effect of centrifugal force on a rotating element. In the case of a *"fly-ball" governor* weights or balls attached to pivoted levers are revolved by the engine and if the speed increases above normal, the balls or weighted levers move outward from the axis of rotation, owing to the increase in centrifugal force. This change in the position of the revolving balls may be transmitted through suitable connecting levers and rods to a valve which partly closes, thus reducing the steam supply. When a governor of this type is applied to a Corliss engine, the release of the steam valves and the point of cut-off is controlled directly by the governor. Most governors of the fly-ball type are equipped with one or more springs which tend to resist the outward movement of the revolving balls.

The *inertia or centrifugal-inertia governor* is attached to the fly-wheel and regulates the speed by varying the position of the eccentric or crankpin that operates the valve. Generally, this governor has an inertia bar with enlarged ends to increase the weight at the ends. The bar is pivoted at some central point. Speed variations cause a slight movement of the inertia bar about its bearing in one direction or another, and the bar is linked so as to change the position of the eccentric, which changes the point of cut-off. If the speed increases, the inertia bar lags behind

momentarily and the steam is cut off earlier during the stroke because the eccentric swings inward and shortens the travel of the valve. If a sudden increase of load should cause the engine to run slower, the bar, as a result of its inertia, would tend to continue running at the faster speed, which would swing the bar forward about its bearing in the direction of rotation, thus increasing the valve travel and admitting more steam to the cylinder by delaying the point of cut-off.

Governors, Water-Wheel. See Water-wheel Governors.

Grade of Grinding Wheel. See Grinding Wheel Grade and Grain.

Graduating. The dividing of circular and straight scales into a given number of equal spaces or divisions is known as graduating. The type of machine or tool used for graduating and the method of producing the graduation marks or lines varies with different classes of work, depending upon the degree of accuracy necessary and the form of the parts to be graduated. The work of graduating may be divided into two branches, which include, first, the method of spacing, and second, the means for making suitable marks or lines upon the parts to be graduated.

The machines used in laboratories and by tool and instrument manufacturers, for graduating various kinds of straight scales, may be classified as the *precision screw* type and the *pantograph* type. The former is equipped with a very accurate lead-screw, which, by means of a suitable indexing or spacing mechanism, is rotated an amount depending upon the spacing required, and as this screw actuates the work-holding table, a tool that is given a cross-movement makes graduation lines either in a "resist" or directly upon the work. The pantograph machines have a pantograph mechanism which serves to reproduce, on a smaller scale, the graduation lines or figures which have been previously cut in a pattern or master scale.

The marks or lines which represent divisions or spaces on graduated scales, etc., may be formed by the etching process, by the direct-cutting action of a tool, or, for some grades of work, by the stamping or impression process. With the etching process, the part to be graduated is first covered with some acid-resisting material or "resist," as it is called, and then the lines or figures are cut into this resist by a mechanically-guided graduating tool, thus exposing the metal wherever these lines or figures are made. An etching acid is then applied, and, wherever the metal is exposed, the acid eats into the surface and forms the division lines. When very fine graduation lines are needed the general practice is to employ the direct-cutting method, since the marks obtained by a very sharp-pointed tool are finer and more accurate than

is possible to obtain by the etching process. See Etching "Resists" and Etching Fluids.

Graduating on Glass. When graduation lines are etched on glass, a resist of paraffin or beeswax may be used. The lines and any other additional figures or designs required are then drawn into the resist the same as when operating on metal. Concentrated hydrofluoric acid is used for etching glass, and a little pigment is sometimes rubbed into the etched lines to make them more visible.

Grainal. These alloys are used to produce desirable properties in steel. One contains 25 per cent vanadium, 15 per cent titanium, and 10 per cent aluminum; another contains 13 per cent vanadium, 20 per cent titanium, and 12 per cent aluminum; while a third contains 20 per cent titanium, 20 per cent aluminum, and 6 per cent zirconium. They make possible the production of steel of uniform properties from heat to heat; the conversion of some water-hardening steels into oil-hardening; the production of steel of unusual physical properties at economical cost; and the addition of alloys to steel without complicating the usual steel making processes.

"Grain" of Grinding Wheel. See Grinding Wheel Grade and Grain.

Gram-Calorie. Gram-calorie is a thermal unit based on the metric system, designating the amount of heat required for raising the temperature of one grain of pure water one degree C. One gram-calorie = 0.003968 British thermal units; 1000 gram-calories = 1 kilogram-calorie.

Granite. Granite is one of the rocks or stones consisting principally of quartz and felspar, which is valuable as a building material, as a material for foundations, etc. The general properties of granite may be specified as follows: The weight of granite per cubic foot is 170 pounds; the specific gravity averages about 2.72; the compressive strength per square inch is about 15,000 pounds; the shearing strength per square inch is about 2000 pounds; the tensile strength per square inch is about 1500 pounds; the modulus of elasticity is about 7,000,000; and the coefficient of linear expansion due to heat, for each degree F., is 0.000004.

Graphalloy. Graphalloy is a trade name for a metallized graphite made by forcing molten metal into graphite of a porous nature by the application of air pressures up to 5000 pounds per square inch. Graphalloy is adapted for bearing bushings where the application of oil is either objectionable, difficult, or likely to be neglected, and also for brushes and contacts for electrical machinery.

Graphic Formula. In chemistry, a graphic formula is one which shows the valence of the atoms and the manner in which they are united in a compound.

Graphite. Graphite is a form of mineral which consists of the chemical element carbon. Graphite is very dark in color with a bright metallic luster, and is one of the softest of the minerals. Its specific gravity is about 2.2. Graphite occurs in nature mainly in crystalline rocks, and is also produced artificially on a large scale in the electric furnace. In the industries, graphite is used as a lubricant, as a material for crucibles, for foundry facings, and as a material for electrodes. It is also widely used in the manufacture of pencils, polishes, and paint. A special variety of graphite used for lubrication purposes is known as "deflocculated graphite." Deflocculated graphite, when suspended in water, is known by the trade name "aquadag." When suspended in oil, the trade name "oildag" is used. Graphite has valuable lubricating properties. See Deflocculated Graphite.

Graphite Crucible. This is a pot or container made from a mixture of Ceylon graphite, clay, and pure sand, used for the melting of metals. Graphite crucibles are more generally used than clay crucibles, because they can be recharged cold, will stand rough handling, and have a longer life.

Graphitic Carbon. This is carbon in the form of graphite. In cast iron it is merely mixed with the iron and is not in chemical combination with it. For the effect of graphitic carbon in cast iron, see Cast Iron.

Graphitic Steel. Graphitic steel contains approximately 1.50 per cent total carbon and around 1.00 per cent silicon, and in one form carries approximately 0.25 per cent molybdenum. It can readily be forged to shape from the "as rolled" condition, but before machining to shape it must always be normalized and annealed; this precipitates part of the total carbon in the form of free graphite, uniformly distributed throughout the steel, and develops the spheroidized pearlitic structure so well suited to good machining. Quenching develops a martensitic structure, the steel reacting in much the same manner as eutectoid tool steel. The resulting dies and punches show remarkable hardness and toughness, and are highly resistant to wear. For water-hardening uses, no molybdenum is added, this type of graphitic steel being known as "Graph-sil." When special toughness is required or freedom from distortion is essential, the oil-hardening "Graph-mo" is used.

Graphitizing. Graphitizing, according to the S.A.E. definition, is a method of annealing cast iron whereby some or all of the combined carbon is transformed into free or uncombined carbon.

Grate Area. The grate area is the area of the grate of a furnace, usually expressed in square feet. A simple rule for calculating the grate area of a boiler when the probable rates of combustion and evaporation are known is as follows: Multiply the horsepower of the boiler by 34.5 and divide the result by the product of the rate of combustion times the rate of evaporation; the quotient is the grate area in square feet.

Gravity. The attractive force that exists between the earth and all bodies at or near its surface is called "gravity." Weight is due to gravity. A body has weight because it is pulled downward by the force of gravity, and the amount that it weighs is a measure of this pull. A piece of iron, for example, weighs one pound when it is of such a size and density that it is drawn to the earth by a force equal to that which attracts a standard pound weight. The weight of a body (that is, the force by which it is attracted to the earth) varies slightly with the locality. Thus weight varies with altitude. A body weighs the most at the surface of the earth, as the attraction is there the strongest. Below the surface its weight decreases in the same ratio that its distance from the center of the earth decreases. Above the surface, the weight decreases in the same ratio that the square of the distance from the center increases. Weight also varies with the latitude, or distance north and south of the equator. In passing from the equator to either pole, the attraction of gravity increases by 1/568 of its original amount. This is due to the fact that the earth is not a perfect sphere, the polar diameter being 26 miles shorter than the diameter at the equator. At the poles, however, a body would actually weigh more than this, or about 1/193 more than at the equator. The difference, 1/289, is due to the rotation of the earth on its axis, the effect of which is to produce a force directly opposite to that of gravity (centrifugal force), which is greatest at the equator and diminishes in moving from it, until at the poles it becomes zero.

Falling Bodies: Under the influence of gravity alone, all bodies fall to the earth with the same velocity and with the same acceleration. The fact that heavy bodies actually fall more rapidly than those of less weight or density, as would be observed in the dropping of a stone and a leaf, is due solely to the greater retarding effect of the air upon the latter. Weight does not affect the time of fall. Weight is the measure of the attractive force of gravity, and if one body weighs twice as much as another, the attraction of gravity upon it is two times as great as upon the lighter body; but as this force must accelerate twice as great a mass in the former body as in the latter, the velocity of each must be alike. An apparatus used to prove this consists of a long glass tube with closed ends, so arranged that the air can be exhausted.

When this has been done, it is found that objects of varying sizes and weights will fall from one end of the tube to the other with equal rapidity. The value of the acceleration due to gravity is commonly denoted by the letter g. The acceleration increases with the latitude and decreases with the elevation above the level of the sea. Its value at the level of the sea in the latitude of New York is 32.16 feet per second. (In the metric system g equals 9.81 meters per second at 45 degrees latitude and sea level.) As the velocity increases (is accelerated) 32.16 feet (or g) every second, the velocity after T seconds will be:

where V = velocity in feet per second. The space in feet passed through by the falling body in T seconds equals the average velocity (which is $\frac{1}{2}V$) multiplied by the time:

$$S = \tfrac{1}{2}\, VT,$$

where S = space in feet which the falling body passes through in T seconds. These two formulas are the basis of all formulas relating to falling bodies.

Gravity Curve. An easy working cam curve is the one known as the "gravity curve." This curve has a constant acceleration or retardation bearing the same ratio to the speed as the acceleration or retardation produced by gravity; hence its name. A very close and satisfactory approximation for the gravity curve, and one that entails less work than the theoretical, is shown by the diagram. The method of drawing is similar to the one used for harmonic motion, excepting that an ellipse takes the place of the semi-circle. It can be seen very readily that the ratio of the major and minor axes will determine the character of the cam curve. To obtain a curve that will approximate the gravity curve, the line representing the stroke of the cam should be used as the minor axis and the ratio of major axis to minor axis should be $1\frac{3}{8}$ to 1 or 11 to 8. By dividing the semi-ellipse and line of angle of motion into the same number of equal parts, and projecting, points on the curve are obtained.

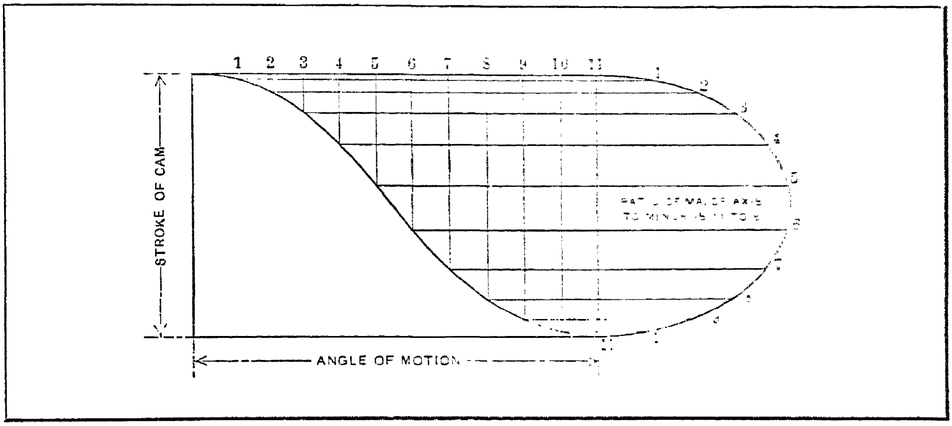
Gravity Idler. The gravity type of idler used in conjunction with many belt drives, consists of a weighted idler pulley, so pivoted from a long arm that the idler runs near the small pulley against the loose side of the belt, in such a way as to increase the arc of contact of the belt on this pulley. These idlers are of especial value on difficult drives where there is a large difference in the diameter of the driver and driven pulleys. See Belt Drives, Short-Center Type; also Lenix Belt Drive.

Gray Cast Iron. See Cast Iron.

Green Brass. When brass contains from 20 to 25 per cent of zinc, it has a greenish-yellow color. Because of this color it is known as "green brass."

Green Sand Core. A part of a foundry mold inserted in the mold cavity so as to form either a hole or a recess in the casting; made from ordinary green molding sand and not dried or baked. This is the cheapest kind of core that can be used for molding, but can only be used for plain cylindrical shapes or for patterns having such recesses that the core can be shaped in the molding sand in connection with the regular molding work.

Grenet Cell. This is a primary cell or battery which is practically identical with the Bichromate Cell, which see.



Approximate Gravity Curve

Gridiron Valve. This is a multiple-port type of engine slide valve designed to give a maximum opening with minimum travel. Both the valve and its seat contain a number of narrow openings or ports, so that a short movement of the valve will open or close a comparatively large opening. For example, if the steam valve has twelve openings, each $\frac{1}{4}$ inch in width, a movement of $\frac{1}{4}$ inch of the valve will open a space $12 \times \frac{1}{4} = 3$ inches in length.

Grinders, Floor-Stand Type. This type of machine is used for "hand grinding" and the grinder head is supported by a pedestal or floor stand. Machines of this type generally mount two wheels—one on each end of the spindle. Floor stands generally mount grinding wheels from 12 to 24 inches in diameter and from 2 to 4 inches thick. The spindle may be driven by a belt or the stand may be a self-contained machine, with an electric motor at the center, whose shaft is also the wheel spindle. The stand should be equipped with adequate wheel guards, to protect the operator

against wheel breakage, and which can at the same time act as dust hoods if properly connected to an exhaust system. Castings weighing from 2 to 50 pounds are usually snagged on floor stands. For smaller pieces weighing two pounds, or less, it is more economical to use bench stands. They are similar in construction in every way to floor stands, but are smaller and have no pedestal.

Grinders, Portable Class. Grinders which may properly be included in the portable class are made in quite a variety of forms.

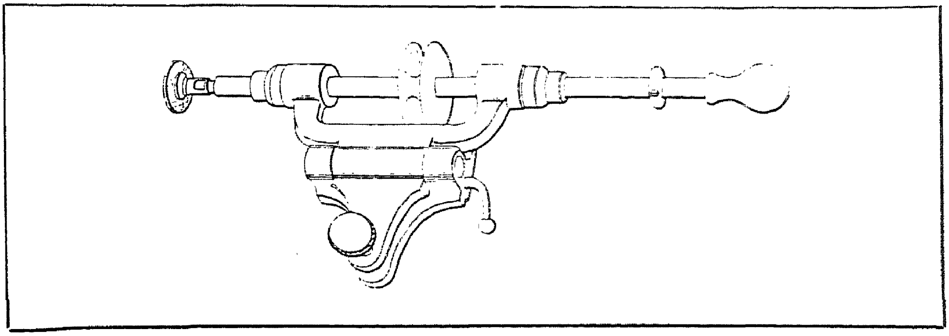
A type which is used for many different purposes is commonly known as a "toolpost grinder," owing to the fact that it is held in the toolpost of a machine like the lathe, planer, or shaper. Modern grinders of this class are electrically driven, the motor being connected directly in the grinding wheel. The current is supplied ordinarily from a lamp-socket, connections being made with an ordinary lamp cord. These toolpost grinders are very often used for truing lathe centers, grinding small work in lathes (when a regular grinding machine is not available), and they also enable the planer or shaper to be used for grinding plane surfaces. When used for this purpose, the grinder is clamped in the toolpost in such a position that the axis of the grinding wheel is parallel with the surface to be ground, and the revolving wheel is used in practically the same way that a tool would be used for planing.

Hand-manipulated Type: Small portable grinders of the hand type are used for finish grinding miscellaneous parts or surfaces which, because of their shape or location, require a small grinding wheel and hand manipulation. Such grinders are used extensively in diemaking for grinding out cavities or other surfaces. They are applied to various dies used in forming sheet metals and also in finishing certain cavities or passages in die-casting dies, metal patterns, etc. There are several types of these small portable grinders. Some are driven by electricity, others by air, and there is also the flexible-shaft type. Grinding wheel manufacturers make special shapes of small wheels for use in these portable grinders. These wheels are made in the form of disks, cones, and in cylindrical, spherical and other shapes. Portable grinders greatly simplify the machining of many cavities or other surfaces, especially if the part has been hardened.

Grinders, Swing-Frame Type. The swing-frame grinding machine was designed for the purpose of removing the fins, gates and nails left by and in molding, from castings too heavy to be conveniently lifted by hand. One wheel only is mounted on a machine, and the arm on which the wheel is mounted has a large radius of swing, as well as being designed to travel laterally on a track. Swing frame machines are the heavy-duty machines in

the foundry and are rigidly constructed. Great pressures of wheel on work are possible because the operator bears his whole weight at times on the handles of the machine. Wheels from 12 to 18 inches in diameter and from 2 to 3 inches thick are commonly employed.

Grinding Allowances. The amount of stock that can economically be removed by grinding depends largely upon the size and power of the grinding machine. The modern practice, when using heavy machines, is to reduce the work in a lathe to within somewhere between 1/64 and 1/32 inch of the required diameter and then finish by grinding. The lathe is simply used for roughing, and the stock is removed by taking one or more coarse cuts, leaving a rough surface on the work. It is practicable, in many cases, to grind bar stock from the rough without any preliminary turning operation, although most work is first turned. In using a



Push- or Traverse-spindle Grinding Attachment

light grinder, the allowance for grinding must be comparatively small and is governed more or less, in any case, by the size and character of the work, as well as by the power and stock-removing capacity of the grinding machine. The grinding allowance for parts which have to be hardened naturally depends, to some extent, upon the shape of the part and the liability of distortion due to the hardening process.

Grinding Attachments, Push-Spindle. As the bench lathe is used almost exclusively for fine precision work, it is necessary, in many cases, to finish bored holes and exterior surfaces by grinding. A typical design of an internal grinding attachment for the bench lathe is shown by the illustration. The spindle, which is free to move in a lengthwise direction, is held by two bearings, and, when grinding, it is traversed by hand. This device is sometimes called a *push-spindle grinding attachment.* The spindle is driven by a round belt from an overhead countershaft.

The handle at the end of the spindle, which is simply a loose knob, is usually held between the thumb and the index finger, and the sensitive touch secured in this way enables a skilled workman to determine if he is working under proper conditions, as soon as the wheel comes into contact with the work.

Grinding Attachment, Toolpost. This type of grinding attachment is used on lathes for light grinding operations and, in some cases, for very light milling or other machining operations on gages, jigs, dies, etc. The attachment is held by a shank that is clamped in the regular toolpost and its spindle is driven by a small motor.

Grinding, Fixed-Wheel. See Fixed-Wheel Grinding.

Grinding, Form. See Form Grinding.

Grinding Machines. Grinding machines were used originally almost exclusively for truing tool steel parts which had been distorted by hardening, and are still indispensable for work of this class. The great improvements which have been made, both in grinding machines and abrasive wheels, however, have resulted in the application of the grinding process to the finishing of a great many unhardened parts. In either case, the work, as a rule, is first reduced to nearly the required size by turning in some form of lathe, and then it is ground to the finished dimension. After a part has been hardened, grinding is the only practicable method of truing it. On the other hand, unhardened pieces can be finished by other means, but grinding is preferable for most cylindrical work, because it enables parts to be finished accurately to a given diameter in less time than would be required by any other known method. Many different types of grinding machines have been developed for handling the various kinds of work to which the grinding process is applicable. The machines used for grinding cylindrical parts, such as shafts, piston-rods, etc., are called *cylindrical grinders,* whereas the type used for grinding holes in bushings, gears, milling cutters, etc., are known as *internal grinders.* There are also *surface grinders* for finishing flat or plane surfaces, and, in addition, types that are designed for specific kinds of work. The first commercial grinding machine, built in 1864-1865, was used only as a precision machine for grinding hardened parts and correcting slight errors due to warping in hardening. From this small beginning, the grinding machine has passed through a remarkable development. See type of machine as, for example, Cylindrical Grinding Machines; Centerless Grinding; Disk Grinders; Internal Grinding Machines; Surface Grinding Machines.

Grinding, Plunge-Cut. See Plunge-cut Grinding.

Grinding Screw Threads. See Thread Grinding.

Grinding Wheel Bonding Processes. See Bonding Processes for Grinding Wheels.

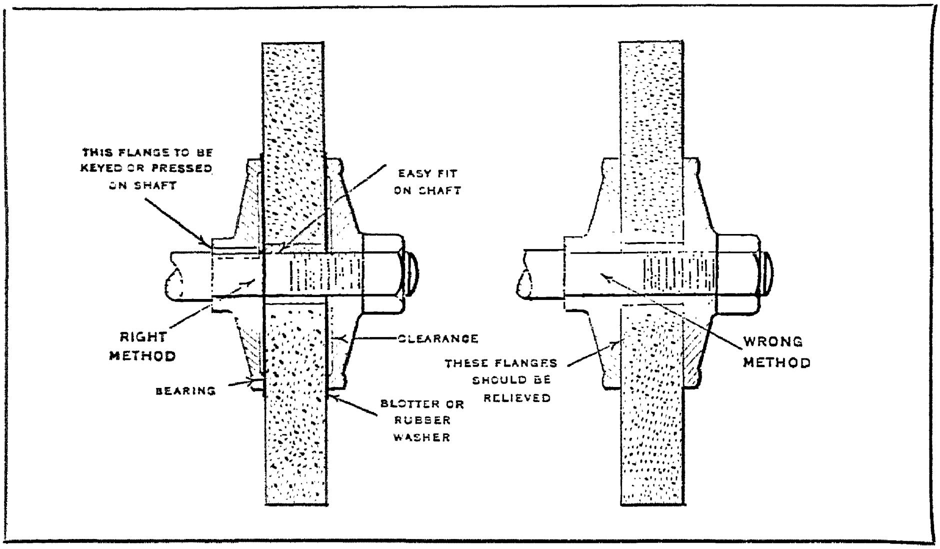
Grinding Wheel Bushings. Most grinding wheels are bushed to size with lead, babbitt, or other soft material, the exception being very small wheels, and very large wheels which are to be held in a chuck or in some way other than by flanges on a spindle. The bushing process follows that of truing. The bushing must be true with the sides of the wheel, otherwise the wheel may break when placed on the spindle and the flanges tightened. The diameter of the hole should be from 0.002 inch to 0.005 inch larger than the diameter of the spindle on which the wheel is to be mounted. If the hole is smaller, breakage may occur by forcing the wheel. If the hole is larger than this limit it is difficult to mount the wheel so that it will run true and straight, and, too, it may be clamped in the flanges in such a position as to be out of balance. Lead is the most commonly used material for bushing. Babbitt, being a little harder, is better for the severe duty to which coarse wheels and large cup wheels are subjected. If the lead is too soft, the bushing will not retain its shape and will be easily damaged in mounting.

Grinding Wheel Care. Wheels used in wet grinding should not be allowed to stand partly immersed in water. The water-soaked portion may throw the wheel dangerously out of balance. All wet tool grinders that are not so designed as to provide a constant supply of fresh water should be thoroughly drained at the end of each day's work, and a fresh supply of water provided just before starting.

Grinding Wheel Colors. The color of both aluminum-oxide and silicon-carbide grinding wheels depends on the material used to hold the abrasive particles together, which is termed the "bond." The exact shade, however, is likely to vary somewhat with wheels of the same bond that are produced in the same heat, and so a slight variation in the shade of two wheels does not necessarily indicate a difference in grade. The four most important bonding processes are known as the vitrified, silicate, elastic, and rubber processes, and these names are applied to the grinding wheels produced by them. The use of different bonds permits the manufacture of wheels of different characteristics to suit all classes of grinding. Vitrified wheels are standard for most grinding operations, the other kinds being used when special conditions are encountered. Probably 80 per cent of all grinding wheels are vitrified. Vitrified wheels can be readily distinguished from the other wheels by their reddish or reddish-brown color, and the clean ringing sound which results when they are tapped. Silicate

wheels are easily recognized by their light gray color. Elastic and vulcanized wheels are almost black, but they may be distinguished by their odor when subjected to the friction of a grinding operation or when a small part is burned. Elastic wheels emit an aroma, whereas rubber wheels give off the odor of burning rubber.

Grinding Wheel Grade and Grain. The term "grade," as applied to a grinding wheel, refers to the tenacity with which the bond holds the cutting particles or abrasive grains in place, and not to the hardness of the abrasive. A wheel from which the abrasive grains can easily be dislodged is called "soft," or of "soft grade," and one which holds the grains securely is referred



Correct and Incorrect Method of Mounting Grinding Wheels

to as a "hard wheel." By varying the amount and composition of the bond, wheels of different grades are obtained. The grade is designated either by letters of the alphabet or numbers. According to the system employed by several manufacturers, the letter M, and possibly several adjacent letters, represents a medium grade, and the successive order of letters preceding and following M denotes softer and harder wheels, or vice versa. This method of grading wheels is not universal, as a standard system has not, up to the present time, been adopted. The grain or coarseness of a wheel is designated by numbers. See Abrasive Grit Number.

Grinding Wheel Mounting. Grinding wheels should fit freely on their spindles but without unnecessary play. If a wheel is

forced onto the spindle, there is danger of starting cracks. The diameter of the flanges should be one-half the wheel diameter (never less than one-third), and the flanges should be relieved recessed to secure an annular bearing at their circumference. (See illustration.) The inner flange should be keyed or shrunk onto the spindle. Compressible washers of blotting paper or rubber should be placed between the wheel and the flanges, to distribute the clamping pressure evenly. The flanges should be clamped just tight enough to hold the wheel firmly. Wheels should be carefully inspected, and be tapped lightly before mounting, as new wheels occasionally burst when first brought up to speed, because of hidden cracks resulting from rough handling in transit.

The right and wrong methods of mounting grinding wheels are shown by the illustration. The right method requires the use of relieved flanges with compressible washers between the wheel and flange. The relieved flanges give a bearing on the outer edge and the washers distribute the pressure evenly when the flanges are tightened, by compensating for any imperfections or unevenness in either wheel or flange. When the flanges are straight and no washers are used, tightening the spindle nut tends to concentrate the pressure near the center of the wheel instead of distributing it over the entire flange surface, thus creating a dangerous condition. The hole through the wheel bushing should be about 0.005 inch larger than the size of the spindle so that the wheel will slide on without cramping, but still have a fairly good fit on the spindle as well as against the inside flange.

Ends of grinder spindles should be so threaded that the nuts on both ends will tend to tighten as the spindles revolve. Care should be taken in setting up machines to see that the spindles are arranged to revolve in the proper direction, or else the nuts on the ends will loosen. To remove the nuts, they should both be turned in the direction in which the spindle revolves when the wheel is in operation.

Grinding Wheel Selection. In selecting wheels for grinding metals, the physical properties of the metals to be ground serve as a basis for determining whether to use silicon carbide abrasives or the aluminous abrasives. (For information about these two general classes see Abrasives.) The silicon carbide abrasives represented by crystolon, carborundum, etc., differ materially from the aluminous abrasives such as alundum, aloxite, etc. The grains of the former are harder but are also more brittle due to the structure; the grains of the latter, while not as hard, are tougher and do not break apart as easily, thus being able to withstand a greater stress. In addition, the aluminous abrasives admit of a certain range of toughness in their manufacture. On account of the difference in physical characteristics of the two

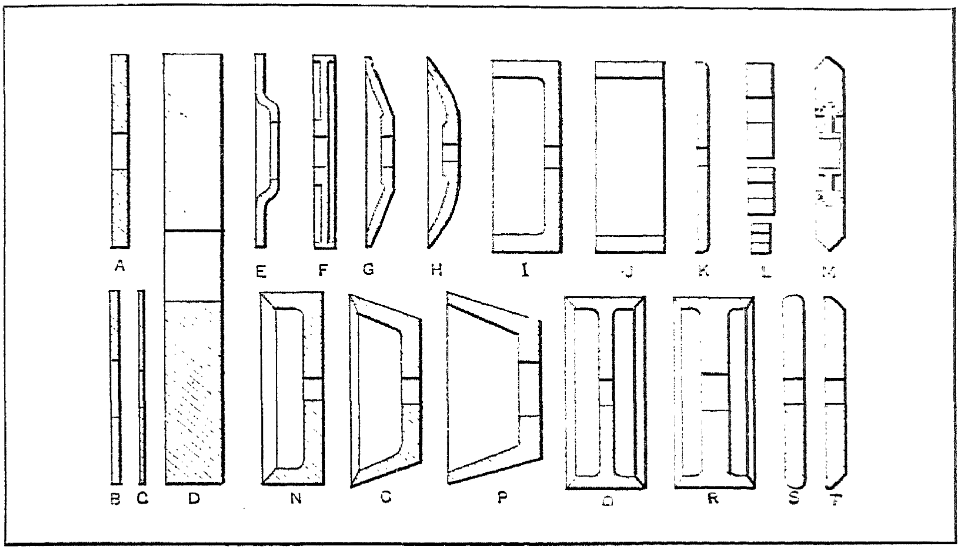
abrasives, a general rule has been established, namely, that aluminous abrasives are used for grinding materials of high tensile strength, and silicon carbide abrasives for those of lower tensile strength. While tensile strength alone is not the criterion, inasmuch as hardness and ductility influence the selection, experience has shown that, in general, the aluminous abrasives are particularly adopted for grinding materials of high tensile strength. For information about different grinding wheels, see kind of wheel as, for example, Elastic Grinding Wheels; Vitrified Grinding Wheels; Vulcanite Grinding Wheels.

Grinding Wheel Shapes. Grinding wheels are made in many different shapes and sizes to adapt them for use in different types of grinding machines and on different classes of work. Plain disk-shaped wheels similar to those illustrated at *A, B,* and *D* are the kind generally used in connection with cylindrical grinding operations. Wheels of this form vary greatly in size, the diameter and width of face naturally depending upon the class of work for which the wheel is used and the size and power of the grinding machine. In modern practice, quite large wheels are used on heavy work. In connection with form grinding, the wheel-face is frequently made wide enough to cover the entire surface of the work; that is, the wheel is dressed to conform to the shape required on the work and the latter is ground by feeding the wheel straight in, there being no lateral or transverse movement.

Very thin or narrow wheels *C* are sometimes used in connection with cutter or reamer grinding, or for cutting off stock. The form of wheel shown at *E* is intended for grinding up to a large shoulder. The wheel is mounted on the end of the spindle and is "dished" at the center so that the retaining nut on the spindle will not project beyond the side of the wheel and strike the shoulder. Wheel *F* is especially adapted for facing the ends of bushings or small shoulders. When the wheel is used for end facing, the grinding is done on the side which is recessed to reduce the contact area to a narrow surface. The saucer or dish-shaped wheels *G* and *H* are extensively used for grinding formed milling cutters, etc., especially on regular tool- and cutter-grinding machines. The cup-wheel *I* is used for grinding flat surfaces by traversing the work past the end or face of the wheel. The cylindrical or ring-wheel *J* is also used for producing flat surfaces, the grinding being done by the end the same as with a cup-wheel. The latter is attached directly to the spindle, but the ring-type of wheel is held in a special chuck. The special form of wheel shown at *K* is used for thinning the points of twist drills when, as the result of repeated grinding, the web at the point becomes too thick, thus increasing the pressure required to force the drill through the metal. The small wheels shown at *L* are

used in connection with internal grinding. These wheels, like all of those shown in the illustration, vary considerably in size, the diameter in any case depending upon the size of the work. The wheels illustrated at *M, N, O, P, Q,* and *R* are employed in connection with a variety of grinding operations on tool- and cutter-grinding machines, whereas wheels *S* and *T* are employed for saw-gumming. Grinding wheels are made in other shapes but most of them are modifications of the forms illustrated.

Grinding Wheel Speeds. The peripheral speed of a grinding wheel is usually between 5500 and 6000 feet per minute, but speeds varying from 5000 to 7000 feet per minute are employed.



Various Commercial Shapes of Grinding Wheels

Plain grinding wheels may safely be operated at higher speeds than cup-wheels or those of special shapes; hard wheels may also be run at a higher speed than soft ones. It is the custom of grinding wheel manufacturers to attach a label to each wheel indicating the safe maximum speed for that particular shape and grade of wheel. These recommended speeds should never be exceeded. A committee appointed by representative abrasive wheel manufacturers, in order to determine safe practices in the use of grinding wheels, recommended the following speeds: A peripheral speed of 5000 feet per minute for vitrified and silicate straight wheels, tapered wheels, and shapes other than those known as cup- and cylinder-wheels, which are used on bench, floor, swing-frame, and other machines for rough-grinding. Speeds exceeding 5000 feet may be used upon the recommendation of the wheel

manufacturer, but in no case should a speed of 6500 feet per minute be exceeded. A speed of 4500 feet per minute was recommended as the standard operating speed for silicate and vitrified wheels of the cup and cylinder shape, used on bench, floor, swing-frame, and other machines for rough-grinding. For elastic, vulcanite, and wheels having other organic bonds, the recommendations of individual wheel manufacturers should be followed.

Affect of Work on Wheel Speed: To a certain extent, the cutting action of an abrasive may be compared with that of a milling cutter. On hard materials having a high percentage of carbon, the wheel must be operated at a lower speed than on soft steel. In general, the softer the metal, the higher may be the speed of the wheel. The high speed reduces, to a considerable extent, the tendency of the wheel to load. In cases where the work revolves during the grinding operation, the speed of the work must be taken into consideration. For example, if the work is revolved at too high a speed, while the wheel runs at the proper speed, the stress on the cutting grains of the wheel caused by the pressure of the work will be materially increased and may tear the grains from the surface of the wheel and decrease the production per wheel.

If the wheel is operating at too high a speed and the work is revolving at the proper speed, glazing will take place rapidly. Again, with the wheel operating at the proper speed and the work at too low a speed, the abrasive will soon be dulled, thus necessitating frequent dressing of the wheel surface. This happens because there is not sufficient action between the work and the wheel to remove the dulled abrasive particles or break them up so that they will present new cutting points. Obviously, production is materially reduced under these conditions.

When a wheel of the most desirable grade for a particular job is not obtainable, a less desirable wheel can sometimes be used with good results if it is run at the proper speed. For example, a soft wheel may be made to act more like a hard one by increasing its speed. A coarse-grain wheel will produce a reasonably smooth surface by increasing its speed, so long as none of the undesirable conditions described are experienced.

Grinding Wheel Standards. Grinding wheels in nine standard shapes, and in a range of sizes for each shape, have been standardized by the Grinding Wheel Manufacturers Association of the United States and Canada. These nine shapes represent practically all of the forms used on standard makes of grinding machines. This standard not only simplifies the stocking of wheels but enables the user to identify accurately any wheel by giving the type number and the important dimensions. The No. 1 or straight type is made in diameters ranging from 1/4 inch up to

36 inches and in thicknesses from ¼ inch up to 4 inches. For internal grinding, this type of wheel is made in diameters from ¼ inch to 4 inches and in thicknesses from ¼ inch to 2½ inches. Complete tables giving the diameters and other dimensions for the nine standard types or shapes will be found in engineering handbooks.

Grinding Wheel Truing. See Diamonds for Wheel Truing.

Grindstones. Most of the grindstones used in the United States come from Huron, Mich.; Berea, Ohio; or from Grindstone Island, Nova Scotia. All of these localities produce several grades. Most Berea stones are rather coarse; those from Nova Scotia are of all grades. Grindstones are natural sand stones, and the cutting material is oxide of silicon (SiO_2), or quartz sand, as it is commonly called. Grindstones are softer when wet than when dry, and they should never be left standing with one side in the water, because, when the stone is again used, this side will be worn away faster than the other.

Mounting: The tendency for cracks to start in grindstones can be overcome by a proper method of mounting. It is good practice to fill the central space around the arbor with cement or lead after the stone is centered. Wooden wedges should never be used. The stone should be supported by flanges of generous proportions, and wooden washers from ½ to 1 inch in thickness (or a double thickness of leather or rubber) should be inserted between the flanges and the stone to compensate for surface inequalities.

Speeds: The grindstones used in machine shops usually have a surface speed varying from 800 to 1000 feet per minute, although these speeds are exceeded considerably in some instances. Cutlery concerns sometimes run grindstones at 3000 or 4000 feet per minute. The safe maximum speed is difficult to determine, because stones from the same quarry vary in strength. As a rule, the speed should be limited to 2500 feet per minute, if the variety of the stone is not known.

Grip Socket. This is a type of drill socket designed to hold and drive taper shank drills and other tools provided with taper shanks. A groove is milled in the shank of the drill or tool, and a key is let into the body of the socket which fits into the groove and is locked securely in place by turning a revolving collar one revolution. When the key is locked, it is impossible for the tool to slip in the socket or to be pulled out until the collar is turned back again to release the key. In the grip socket, the taper shank is not depended upon to act as a driver, but the key takes the thrust.

Grooving. In boilers, grooving is a condition similar to "pitting," consisting of the formation of grooves in the boiler plates.

It is an injury especially dangerous because the grooves may become covered with scale and are, therefore, difficult to locate. It is caused partly by chemical action from oxygen and chlorine released from the feed water, and partly by mechanical action, such as excessive calking, which impairs the surface of the metal and exposes it to the corrosive elements in the feed water.

Ground Stone. What is known as "ground stone" is used by some small tool manufacturers for lapping plug gages, ring gages, etc., and this material is also used, to some extent, in connection with watch manufacture, for fine lapping operations. "Hindostan powder" is produced from a very fine sandstone which is quarried in Indiana. Another ground stone known as "Turkey powder" is composed of pulverized Turkish oilstones, which are imported. An expensive grade of ground stone is known as "Arkansas powder"; it is pulverized Arkansas rock and is quarried in Arkansas. The Turkey powder and Arkansas powder have been used quite extensively in connection with watch manufacture.

Guest's Formula. A formula known as "Guest's formula" was proposed in 1900 by J. J. Guest as the results of experiments made by him on combined bending and torsion. According to this formula:

$$\text{Combined moment} = \sqrt{M_b^2 + M_t^2} = S_s Z_p.$$

In this formula M_b = maximum bending moment; M_t = maximum torsional moment; S_s = permissible working stress in shear; Z_p = polar section modulus. This empirical formula is applicable to parts of circular cross-section and when such material as mild (machine) steel is used.

Guldinus Rules. The Guldinus or Pappus rules provide a means by which the area of any surface of revolution and the volume of any solid of revolution may be found. Briefly stated, these rules are: 1. The area of the surface generated by any line rotating about a fixed axis of revolution equals the length of the line multiplied by the length of the path of its center of gravity. The generating line must lie wholly on one side of the axis of revolution and must be in the same plane as the axis. 2. The volume of a solid body formed by the revolution of a surface about a fixed axis equals the area of the surface multiplied by the length of the path of its center of gravity. The surface must lie wholly on one side of the axis of revolution and must be in the same plane as the axis.

Gulleting File. This file is made of round section in the blunt shape. It is single-cut and used principally for extending the gullets of the teeth of what are known as the "gullet-tooth" and "briar-tooth" saws.

Gunite. Gunite is a strong wear-resisting cast metal which is used for various machine parts such as cams, rails, and miscellaneous wearing surfaces, and also for locomotive cross-head shoes, cylinder and valve bushings and rings, and for certain automotive parts such as brake drums, clutch pressure plates, etc.

Gun Lathe. Gun lathes are designed for turning or for turning and boring naval and coast defense guns, and are sometimes known as *turning and boring lathes.* Comparatively small lathes of this class, such as are used for turning five- or six-inch guns, are often designed along the same general lines as an engine lathe. The larger lathes, however, differ from the engine lathe, both in regard to the design of the bed, the method of imparting feeding movement to the carriage, etc. These larger sizes usually have three or four shears on the bed, and two tool carriages instead of one.

Gun-Metal. Gun-metal or gun-bronze consists of about 90 per cent of copper and 10 per cent of tin with small percentages of lead, iron, and zinc. Gun-metal is used as a bearing metal and for a great many parts, such as valves, valve seats, flanged pipe fittings, etc., where exposed to the action of sea water. The composition follows: Copper, from 87 to 89 per cent; tin, from 9 to 11 per cent; zinc, from 1 to 3 per cent; iron, not exceeding 0.06 per cent; and lead, not exceeding 0.2 per cent. The mixture formed of copper, 88 per cent; tin, 10 per cent; and zinc, 2 per cent, is variously known as "zinc bronze," "Admiralty metal," "government-bronze," and "88-10-2 alloy," although these terms are also frequently applied to all gun-metals. The castings made from gun-bronze are improved by the addition of a small amount of zinc, and the alloy is made harder by the presence of a small percentage of iron, while the small percentage of lead present makes an alloy that is more easily machined. The tensile strength of gun-bronze is from 25,000 to 35,000 pounds per square inch. The elastic limit varies from about 15,000 to 17,000 pounds per square inch, and the metal withstands severe shocks without fracture. The minimum elongation should be about 15 per cent in 2 inches.

Gun-Metal Finish on Aluminum. The gun-metal finish can be given aluminum by immersing it for from six to ten seconds in a cold solution of 12 parts of hydrochloric acid; 1 part of chloride of antimony; and 87 parts of distilled water. After that, thoroughly wash it in running water for several minutes, dry with heat, and lightly buff with a high-speed wheel. The color penetrates the metal and its depth is governed by the length of time it is immersed. If immersed longer than ten seconds, the solution should be weakened, as hydrochloric acid "eats" the metal.

Gun-Metal Finish on Steel. The first operation in obtaining a gun-metal finish is to thoroughly clean the work by methods that will not injure the surfaces. Grease and dirt are readily removed by boiling the work in a solution of one pound of potash to one gallon of water. The potash will last a long time and the water can be replenished as it boils away. When exhausted, the bath can be renewed by adding fresh potash. Scale, oxide, etc., are not removed by washing methods and, hence, a pickling in acid solutions is required. Polished steel surfaces can be pickled by immersing them, in contact with a piece of clean zinc, in a moderately strong solution of the acid potassium sulphate and water. Hydrogen gas is liberated when the zinc decomposes the solution, and this removes the oxide of iron or rust from the steel. Another good pickling solution for steel is made of 20 parts of hydrochloric acid and 80 parts of water. Iron and steel can also be pickled white, in concentrated nitric acid to which has been added some lampblack. After pickling, the work should always be thoroughly washed and scratch-brushed.

Solutions for Gun-metal Finishes: Several different chemical solutions have been used successfully in giving steel the gun-metal finish or black color. Among these are the following: Bismuth chloride, 1 part; copper chloride, 1 part; mercury chloride, 2 parts; hydrochloric acid, 6 parts; and water, 50 parts. Ferric chloride, 1 part; alcohol, 8 parts; and water, 8 parts. Copper sulphate, 2 parts; hydrochloric acid, 3 parts; nitric acid, 7 parts; and perchloride of iron, 88 parts. Other solutions have been prepared from nitric ether, nitric acid, copper sulphate, iron chloride, alcohol and water, and from nitric acid, copper sulphate, iron chloride, and water.

The method of applying these solutions and finishing the work is practically the same in all cases. The surface of the work is given a very thin coating with a soft brush or sponge that has been well squeezed, and is then allowed to dry. If put on too thick the surface will be unevenly corroded and white spots will appear. The work is then put into a closed retort to which steam is admitted and maintained at a temperature of about 100 degrees F. until covered with a slight rust. It is then boiled in clean water for about fifteen minutes and allowed to dry. A coating of black oxide will cover the surface, and this is scratch-brushed. After brushing, the surface will show a grayish black. By repeating the sponging, steaming, and brushing operations several times, a shiny black surface will be obtained that is lasting. For the best finishes these operations are repeated as many as eight times.

Gunter's Chain. Gunter's chain is a chain used by surveyors for land measurements. It has 100 links, each 7.92 inches long.

The total length of the chain is 66 feet, or 4 rods. The handles and the center of the chain are fitted with swivels to prevent kinking. At every tenth link from either end is attached a brass tag with one, two, three, or four prongs to assist in the reading of the measurements. The fifty-link mark is round, so as to be easily distinguished from the others. This chain is not used as much as formerly. See also Engineer's Chain.

Gurley's Bronze. Gurley's bronze is used for the framework for surveyors' instruments, and similar purposes. It contains 16 parts of copper; 1 part of tin; 1 part of zinc; and ½ part of lead. The tensile strength is about 40,000 pounds per square inch; the elongation, about 25 per cent in 2 inches; and the specific gravity, about 8.7.

Gutta-Percha. Gutta-percha is derived from the secretions of the bark of certain trees found in the Straits Settlements and the Malaccan Archipelago. At temperatures between 32 and 80 degrees F., it resembles dark brown leather; at temperatures above 80 degrees F., it softens; and at 150 degrees F., it becomes plastic and can be molded. Upon cooling, it again becomes non-plastic. It oxidizes when exposed to the air, changing its color and becoming brittle. The chief use of gutta-percha is for electrical insulating purposes. It appears in commerce in the forms of blocks or cakes of a grayish appearance. When used for insulation, it is shredded into warm water, kneaded, strained, and rolled into sheets. It is applied to the wire that is to be insulated by special tubing machines, or wound upon the wire in the form of strips. Gutta-percha may be used as an insulating material in the pure state, without admixtures of any kind. It is less porous than rubber, and is therefore more waterproof. For this reason, it is the best material to use as an insulation for submarine cables. Its specific gravity is almost exactly equal to that of water.

Gypsum. Gypsum is a sulphate of lime. It is the same as calcium sulphate, commonly known as plaster-of-paris. See Calcium Sulphate.

Gyration Radius. See Radius of Gyration.

Gyroscope. The gyroscope may be defined, in general, as a mechanism in which a rotating wheel or disk is mounted in gimbals so that the principal axis of rotation always passes through a fixed point. The gyroscope possesses the peculiar quality of resisting any angular displacement of its axis after it has once been set in motion; hence, it is used for securing equilibrium in a great number of devices. Gyroscopes are applied as stabilizers. The gyroscope is also used in a special type of gyroscopic compass which has been highly successful.

H

Hackett K-Copper. A copper alloy especially suitable for use in welding equipment—as for welding tips and holders. Welding tips made from this alloy are said to mushroom less easily than those made of pure copper, require less frequent dressing, and give a greater number of welds during their life. This alloy combines the physical properties of steel and bronze with the high electrical and heat conductivity of copper. In the drawn rod form, it possesses about 83 per cent of the electrical conductivity of pure drawn copper, and in the forged form, 75 to 85 per cent that of forged copper. Hardness, 70 to 80 Rockwell B (125 to 150 Brinell) ; ultimate tensile strength, 70,000 pounds per square inch.

Hacksaw Blades. The straight-tooth blade is generally preferred for power hacksaw machines, although hacksaw blades are made with hook teeth and other forms having positive and negative rake. The objection to the hook-tooth blades is that they "hog in" or bury their teeth whenever they come in contact with edges or walls of the work having an acute angle. Blades having negative rake teeth require more pressure in cutting, but they are often of advantage for cutting parts having thin walls, and in general for work that presents little or no resistance to the pressure of the teeth. The most commonly used pitches are 10 and 14 teeth per inch. The 10-pitch blades are used to cut heavy cross-sections, while the 14-pitch blades are used for medium and light work. On the extremely hard materials of small cross-section, where a heavy pressure must be applied, a fine-pitch blade is necessary, so that the pressure can be distributed over enough teeth to prevent the points of the teeth from crumbling under the pressure. On the other hand, in soft metals, blades of a coarser pitch provide chip space for the larger and heavier chips that a heavy-blade pressure produces in the softer metals.

Tests have shown that steel for saw blades should contain from 1.00 to 1.25 per cent carbon, 0.55 to 2.00 per cent tungsten, 0.20 to 0.50 per cent manganese, 0.20 to 0.80 per cent chromium, and about 0.25 per cent vanadium. Another well-known manufacturer of saw blades keeps the carbon content between 0.80 and 0.90 per cent, but increases the tungsten content from 2.00 to 3.60 per cent, thereby obtaining what is claimed to be an unusually tough and hard blade. The high carbon content blades are not so suitable for high tension as the medium carbon blades; but they are often

found to cut better under medium pressures and high cutting speeds, while the lower carbon content blades often cut best on materials that call for a heavy feed or pressure, but a medium or low cutting speed.

High-carbon blades are recommended for mild steel, where high speed and medium pressure is used, and the lower carbon blades with higher tungsten content for alloy steels, where medium cutting speed and heavy pressures are used. If a great deal of sawing is done in one class of steel, the maximum cutting speed may be determined as follows: Increase the cutting strokes per minute, by 5 for each piece cut off until the temper is drawn in the blade in spite of the cooling lubricant. Then reduce the cutting strokes per minute, about ten strokes, and the most efficient cutting speed has been obtained.

Hacksaw Cutting Speeds. As the cutting action of a hacksaw is not continuous and the speed is not uniform, the average cutting speed in a power hacksaw machine should be considered. Approximately, the cutting speed of the first and last quarters of the stroke may be assumed to be one-half the speed of the stroke in the second and third quarters. For example, assume that the hacksaw has a 6-inch stroke. Then the first $1\frac{1}{2}$ inches of blade travel is accomplished at half the speed of the next $1\frac{1}{2}$ inches of travel, which completes half the stroke. The third $1\frac{1}{2}$ inches of blade travel is accomplished at the same speed as the second, and finally the fourth and last $1\frac{1}{2}$ inches of travel is again accomplished at one-half the speed of the two middle fourths; or briefly, the middle 3 inches of the stroke is traveled at an average speed of twice that of the ends, and this is the cutting speed to be reckoned with.

Lay out a half circle, and connect each end of the half circle by its diameter. Divide the arc of the half circle into three equal spaces. Project the division points down to the diameter, and it will be seen that the length of the middle space, measured on the diameter, is twice the length of the end spaces. The two middle fourths of the stroke are traveled in one-third of the half-circle or in one-sixth of the time required for one complete revolution of the crankshaft. Hence, if the saw blade continued to travel at the same cutting speed as it does during the middle three inches of the stroke for an entire revolution of the crankshaft, it would travel six times three inches, or eighteen inches per revolution. From this we obtain the cutting speed in feet per minute as equal to R. P. M. of crankshaft $\times \frac{6 \times 3}{12}$. For example if the crankshaft is running at 100 revolutions per minute, and the stroke is 6 inches, the cutting speed would be 150 feet per minute; at 80 revolutions per minute, it would be 120 feet per minute;

and at 50 revolutions per minute, 75 feet per minute. When a given cutting speed in feet is required on a machine having a 6-inch stroke it is only necessary to see that the revolutions per minute of the crankshaft or the cutting strokes per minute equal two-thirds of the cutting speed expressed in feet. Assume that for a given case a cutting speed of 90 feet would be satisfactory, when using a cutting lubricant. Then the cutting strokes per minute with a 6-inch stroke should be 60.

Hacksaw Machines. The power hacksaw machine, in its simplest form, merely provided means for reciprocating a hacksaw frame by mechanical power. Gradually, a great many improvements have been made in these machines, until now they constitute a distinct type in the machine tool class. The first improvement made in machines of this kind was to apply weights to give an adequate cutting pressure to the saw blade. The weight of the saw frame, in addition to sliding weights, is today utilized in several power hacksaw machines for obtaining varying pressures on the blade.

Another power hacksaw machine employs a ratchet feed. The blade pressure is varied by changing the compression of a spring that supplies the power for the ratchet fingers, this change being made through a lever on the side of the machine. Another power hacksaw machine is so designed that the blade pressure is applied mainly from an oil cylinder, the pressure in which is produced by a pump. The saw frame of still another design does not travel downward through an arc, but instead is mounted on a double-bearing slide, so that the blade always travels along parallel lines. The saw frame is brought down by means of a screw and nut mechanism actuated intermittently by a ratchet and pawl. Between the ratchet and the screw is located a friction disk that prevents excessive pressure from being exerted on the blade.

Hadfield's Steel. The steel known as Hadfield's steel contains about 12 per cent of manganese and from 0.8 to 1.25 per cent of carbon. This steel is very ductile and hard. The ductility of the steel is brought out by sudden cooling, the process being opposite to that employed for carbon steel. Hadfield manganese steel is used for car wheels, ore and rock crushers, mining machinery, and, in general, where a steel that will resist abrasion is required. It is very hard and cannot be machined with ordinary tools. Parts made from manganese steel are, therefore, cast and subsequently ground on the finished surfaces.

Hafnium. Hafnium is found in all zirconium minerals in amounts ranging from 2 to 20 per cent, and is sufficiently abundant to be available for commercial purposes. It is also present in so-called commercially pure zirconium oxide and salts

of zirconium. In chemical properties, it closely resembles zirconium. It has a very high melting point and high power of light emission.

Half-Nuts. The term "half-nuts" is applied to the two-part nut used on engine lathes for engaging and disengaging with the lead-screw. The half-nuts are opened or closed by a lever and are used to control the movement of the lathe carriage while cutting screw threads.

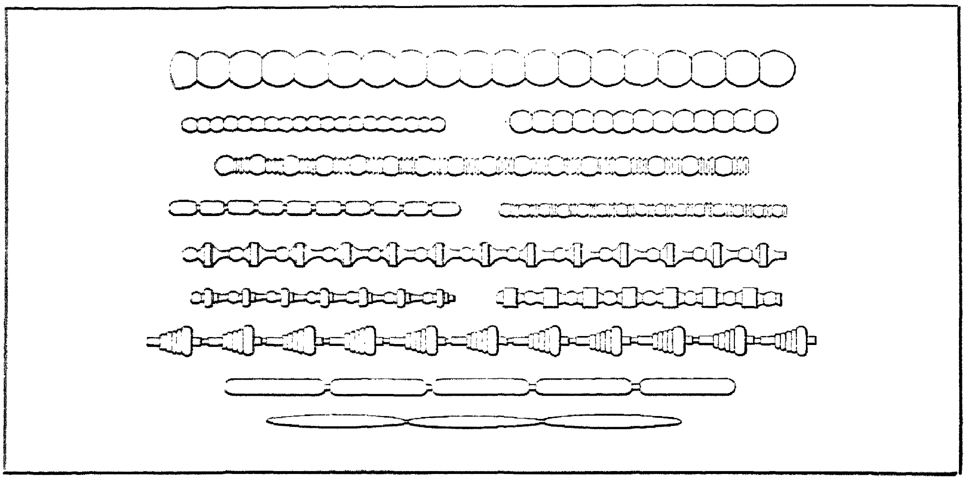
Half-Open Tailstock. This is a special design of tailstock for bench lathes in which the upper part of the spindle bearing is removed, so that the tailstock spindle may be readily lifted out of place. This tailstock is used on light delicate work when different tools are employed, the open construction enabling the spindle to be rapidly removed or replaced.

Half-Round Files. Such files do not form a complete semicircle, as the name implies, the arc being about one-third of the circle. Files of this class are double-cut and mostly bastard, although many are either second-cut, smooth, or dead smooth, the latter being used to a limited extent. Those having teeth finer than bastard are cut single on the convex side. This type is extensively used in machine shops, especially on curved surfaces.

Hammering Machines. Machine hammering, a process akin to swaging, plays an important part in the manufacturing processes in the jewelry and allied trades. A greater variety of work may be hammered than it is possible to swage, and, for this reason, the process is adapted to the forming of ornamental shapes, such as beaded work and jewelry parts, either from solid stock or tubing. The advantage of the process over screw machine production is threefold: Less material is required for the work, the resulting product is stronger on account of the compression of the metal, and the surface of the stock is not removed, thus making it possible to work rolled gold-plated wire and tubing. The hammering machine is not a competitor of the screw machine, although many classes of work can be done better by the hammering machine. The illustration conveys an idea of the range of work that may be done on hammering machines, and particularly shows the value of these machines in the optical and kindred trades. The hammering is done by means of two dies, one forming the anvil and the other the hammer proper. As blows are struck the action takes the form of a continuous vibration. On some classes of work, the upper die strikes 3600 blows per minute. In making dies for work that is to be separated, such as small ornaments or beads, the dies are left with a cut-off at one end, so that, as the work is moved forward in the dies, one section will be completed and cut off at each forward movement of the

stock. In all hammering dies, each succeeding pair of units of the design is slightly smaller than the previous pair nearer the end where the stock enters, so that each set of sections of the dies closes the metal down a little more until it is finished by the last set.

Hammers, Forging. Power hammers such as are used for general forging operations may be divided into two general classes: 1. Those which are actuated by a crank or eccentric that imparts motion to the hammer head through some form of mechanism designed to give the required resiliency or springing action. 2. Those which are operated either by steam or compressed air. Hammers of the first class mentioned are commonly designated



General Classes of Work Produced on a Hammering Machine

as *power* hammers in order to distinguish them from *steam* hammers, although they are all operated by power. Many power hammers such as are used on the lighter classes of forging work are of the vertical design.

Hammer Ratings: Forging hammers are rated in terms of the total weight of the falling or reciprocating parts, including the weight of the ram, piston-rod, piston, and the ram die with its key and dowel. Drop hammers of both steam and air-operated types are rated according to total weight of the ram, piston-rod, and piston, but the dies are not included for hammers of this type. The rating of board drop hammers is based on the total weight of the ram, boards, and the wedges which hold the boards in place in the ram. The weight of the dies is not included in the rating in this type as in other types of drop hammers.

From the foregoing it is evident that if a hammer has a rating of 1 ton this means that the falling or reciprocating parts weigh 2000 pounds, except that the weight of the ram die is omitted in the case of drop hammers. This method of rating hammers does not disclose the energy available, since this is affected by varying speed, stroke, ratio of anvil weight to falling weight, and steam conditions in the case of steam-operated hammers.

Hammer Weight. The ball peen hammers commonly used by machinists weigh from 1 to 1½ pounds. This weight does not include the handle, which is usually from 12 to 14 inches long and made of hickory.

Hand. Hand is an old length measure, equal to 4 inches.

Hand Chaser. A hand chaser is a type of threading tool used either for cutting or chasing external or internal threads. The tool is supported upon a rest and is guided by the hand; it is used mainly on brass work, for slightly reducing the size of a thread that has been cut either by a die or threading tool. A hand chaser may also be used for truing up battered threads in repair work and for similar purposes.

Hand File. This type of file is parallel in thickness from the heel (end of file body next to tang or handle) to the middle, and is tapered, as to thickness, from the middle to the point, the latter being about one-half the thickness of the stock. The edges of the file are usually parallel throughout the entire length but are sometimes drawn in slightly at the point. The hand file is ordinarily preferred by machinists for finishing flat surfaces. The teeth are usually double-cut, bastard, although many files of this type have teeth of second-cut, smooth, or dead-smooth.

Hand Grinding. "Hand grinding" is the term applied to operations where the work to be ground, or the mechanism upon which the wheel is mounted, is held in the hands of the operator. It antedates all other grinding methods and is still used for a large variety of operations, ranging from the grinding of finest tools to the smoothing of large rough castings. The types of machines employed include bench and floor stands, swing frame, flexible shaft, portable electric and pneumatic, and the ordinary wet tool machines for sharpening lathe, planer and other machine shop tools.

Hand-Hole. In a steam boiler, a hand-hole is an opening that is large enough for the hand and arm to enter the boiler for washing out, for making slight repairs, or for inspection.

"Hand" of Milling Cutters. A cutter which rotates to the right (clockwise), as viewed from the spindle or rear side, is said

to be right-hand, and, inversely, a left-hand cutter is one that turns to the left (counter-clockwise) when viewed from the spindle of the machine.

Hand Reamer. A "hand" reamer is used by hand for producing holes that are to be smooth and true to size. The reamer consists of a cutting portion, a shank, and a square by which it is turned when in use. Between the cutting part and the shank, there is a short neck, the purpose of which is to provide clearance for the grinding wheel when grinding the cutting edges and the shank of the reamer.

Handsaw File. These files have the same section as a "three-square" type but differ in that the edges are given the proper bluntness to insure durability; the three-square files have comparatively sharp edges so that they are entirely unfit for filing saws. While the term "taper" is commonly used to denote a file which tapers in a lengthwise direction toward the point, custom has also established the term "taper" as a short name for the three-square handsaw file. One class of handsaw file is tapered to a small point and the teeth are single-cut, second-cut. These files are very extensively used for sharpening handsaws. Some saw files are double-cut, second-cut, these being preferred by some for filing fine-tooth saws.

Hand Screw Machine. Turret lathes of the screw-machine class are sometimes given names which indicate rather definitely the type of machine; for instance, the name *hand screw machine* is often applied to turret screw machines in general, in order to distinguish between the hand-operated type and the automatic type; or the term "hand screw machine" may indicate a design not equipped with an automatic feeding mechanism for the turret slide.

Hand Taps. As the name indicates, hand taps are intended primarily for use by hand, although at the present time regular (standard) hand taps are also used extensively in machines. They are a short tap with thread and shank approximately the same length, the latter having a square to accommodate a tap wrench or other driving mechanism. Hand taps are made in fractional sizes only.

Regular (standard) hand taps are furnished in "taper," "plug," or "bottoming" types the difference being in the number of threads chamfered which is, approximately, as follows: Bottoming taps are chamfered 1 to 1½ threads; plug taps, 2½ to 5 threads; and taper taps 7 to 9 threads.

Two- or Three-Fluted Hand Taps: These are regular (standard) hand taps in every way except that they have a less number

of flutes. Suitable for machine use in tapping tough stringy metal.

Spiral-Pointed Hand Taps: These are regular (standard) hand taps having a fewer number of flutes and wider lands and having the cutting face of the first few threads ground at an angle to force the chips ahead to prevent clogging in the flutes.

Serial Hand Taps: Regular (standard) hand taps in sets of three, the No. 1 being smaller than the No. 2 and the No. 2 being smaller than the No. 3 in pitch diameter, so that the work is distributed among three taps. Used for very tough metal where a full thread cannot be cut at one pass.

Hanger Bolt. A hanger bolt is one having a lag-screw thread at one end and a regular standard thread at the other end, used for attaching shaft hangers to wooden beams or posts.

Hangers, Shaft. See Shaft Hangers.

Hardening Machine. A term that is sometimes applied to machines designed to prevent distortion when parts are quenched for hardening. See Quenching Apparatus.

Hardening Steel. The process of hardening steel consists essentially of heating the steel to the required temperature and quenching it suddenly in some cooling medium. In the actual heating of a piece of steel, several requirements are essential to good hardening: First, that small projections or cutting edges are not heated more rapidly than is the body of the piece, that is, that all parts are heated at the same rate, and second, that all parts are heated to the same temperature. These conditions are facilitated by slow heating, especially when the heated piece is large. A uniform heat, as low in temperature as will give the required hardness, produces the best product. Lack of uniformity in heating causes irregular grain and internal strains, and may even produce surface cracks. A temperature much above the so-called "critical point" of steel (which marks the correct hardening temperature) tends to open its grain—to make it coarse and to diminish its strength—although such a temperature may not be sufficient to lessen appreciably its hardness. The hardening of a carbon steel is the result of a change of internal structure which takes place in the steel when heated properly to a correct temperature.

Critical Temperatures: The temperatures at which internal changes in the structure of a steel take place are frequently spoken of as the "critical" points. These are different in steels of different carbon contents. The higher the percentage of carbon present, the lower the temperature required to produce the internal change. In other words, the critical points of a high-carbon steel are lower than those of a low-carbon steel. In steels of the

commonly used carbon contents, there are two of these critical temperatures, called the *decalescence* point and the *recalescence* point, respectively. A very important feature is that steel containing hardening carbon, i.e., steel above the temperature of decalescence, is non-magnetic. This feature has been taken advantage of as a means of determining the correct hardening temperature, and appliances for its application are on the market. *Harden carbon steel at the lowest possible heat and always on the rising heat.* The grain of the steel corresponds to the highest heat it has received since it was black. If a piece of steel is forged at 1600 degrees F. and allowed to cool to 1400 degrees F. to harden, the grain will correspond to 1600 degrees F.

Hard-Facing. Hard-surfacing or "hard-facing" consists in welding to parts subject to excessive wear, a facing, edge, or point of hard metal which is exceptionally resistant to abrasion. By this method, metal surfaces that normally wear away rapidly in service receive adequate protection from the added layer of wear-resistant alloy. Hard-facing materials are also being applied to numerous parts that may not have to resist abrasive wear at all, but that must be able to resist heat, erosion, corrosion, or a combination of these. Hard-faced valves are now regularly employed in many large power plants for handling high-pressure, high-temperature steam. Many oil refineries are also using hard-faced valves for handling hot sulphur-bearing oil and for other applications where corrosion and erosion are encountered.

In the automotive industry, hard-faced valve-seat inserts are used and hard-facing has been extended to the valves. Valves and seats so protected will last practically as long as the entire engine; moreover, they require a minimum of adjustment. Valve-stem ends are also being hard-faced. Many machine builders are now using hard-faced surfaces, edges, and points in the equipment that they build. To meet the various requirements of hardness, toughness, shock resistance, etc., many hard-facing alloys of widely different compositions have been developed. These may be divided into four broad groups:

Low-Alloy Steels: No sharp definition of composition. Alloying constituents usually less than 5 per cent, but may extend almost to 10 per cent. Not as wear-resistant as the other groups, but have some advantage in toughness and shock-resistance. Manganese, chromium, molybdenum, vanadium, and tungsten are common alloying elements, generally with about 0.3 to 0.6 per cent of carbon.

High-Alloy Steels: Alloying elements in excess of 10 per cent. Almost invariably contain high-chromium for extra wear-resistance. Manganese, cobalt, tungsten, and nickel may also be present. Somewhat more expensive than the low-alloy steels but

have markedly greater wear-resistance which may make for greater economy in the long run.

Non-Ferrous Alloys: Cobalt, chromium, and tungsten are usually the alloying elements. Highly resistant to wear, with a range of different grades having a spread in strength and toughness which makes them suitable for a large number of hard-facing applications. Because of non-ferrous composition, original hardness is practically unimpaired at elevated temperatures.

Tungsten Carbides: The so-called diamond substitutes, which are the hardest and most wear-resistant of all hard-facing materials. Some are almost pure fused tungsten carbides; others contain 90 to 95 per cent tungsten carbide, with the remainder usually cobalt, nickel, or iron. Generally furnished in the form of small castings, known as inserts, or as welding rods, in which the hard particles are packed in steel tubes. Because of their extreme refractoriness, these compounds are not melted or otherwise greatly affected by the oxy-acetylene flame. They are "wetted" by the molten metals and become fused in place—much as a lump of tinned steel might be soldered to a piece of copper. Thus they are held in place without difficulty.

Materials That Can Be Hard-Faced: All plain carbon and low-alloy steels can be processed by this method, provided the carbon content is not substantially in excess of 0.5 per cent. Steels having higher carbon and alloy contents require, under some circumstances, special heat-treatments subsequent to the surfacing operation, and a pre-heating of the part to be surfaced may even be required. Gray cast iron and alloy cast iron are readily hard-surfaced. On the other hand, brass, copper, or bronze cannot be hard-surfaced because of their relatively low melting points.

The selection of a suitable base material for hard-facing is important. For parts requiring considerable resistance to shock and impact, such as hot and cold trimming dies, S A E 3140 steel has proved to be a particularly ideal base material. This steel will not mushroom under impact, since it can be given its standard heat-treatment after hard-facing.

Application of Stellite: Stellite welding rod can be applied by either the oxy-acetylene or the electric arc process, although the former is always preferred, since dilution of the hard-facing deposit with iron from the base metal can be held to a minimum. Another factor to be considered in connection with the arc method is that approximately 8 to 10 per cent of the electrode is lost through volatilization and spattering. Briefly, there are three important points to be borne in mind: (1) The surface to be hard-faced should be clean, free from dirt and scale; (2) an excess acetylene flame should be used; (3) the surface should be brought only to a sweating heat and not melted.

The aim in applying Stellite is to flow the alloy over the surface of the base metal when the latter is at sweating heat. If this is propely done, a strong junction is secured without any appreciable inter-alloying of the two metals. The exceptional properties of Stellite depend upon its non-ferrous composition of cobalt, chromium, and tungsten. Dilution with iron would reduce its ability to resist abrasion. An excess acetylene flame must be used in order to secure the proper sweating of the base metal. It is necessary to see that no particles of scale are covered during the process. If these simple precautions are taken, any welder can, with a little practice, produce a good hard-facing job.

If the electric arc is used, the polarity should be reversed, making the rod the positive electrode. In using the arc, it is impossible to avoid some inter-alloying of the two metals, but this should be kept to a minimum. A 1/4-inch Stellite rod requires 175 to 200 amperes, and a 5/16-inch rod, 225 to 250 amperes. In the majority of cases, hard-facing deposits range from 1/16 to 1/4 inch thick.

Hardie. The *hardie* is a form of chisel for use in conjunction with an anvil. It is made with a square shank to fit the hardie hole in the anvil, and is used for light cutting, such as trimming the ends of small forgings and cutting light stock. The piece to be severed is laid upon the chisel edge of the hardie and is struck with a hammer.

Hardness of Steel and Tensile Strength. There is a constant relationship between the ultimate tensile strength of steel and its hardness; hence the latter may be determined if the former is known, or vice versa. The following simple rules show the approximate relationship between tensile strength and hardness, as determined by both the Brinell and Rockwell tests.

Brinell hardness = tensile strength × 0.002 approximately

Rockwell hardness (C scale) = tensile strength × 0.0002 approximately

Example—Tensile strength of S A E nickel-chromium steel No. 3230 when hardened and drawn to 1100 degrees F. is 120,000 pounds per square inch. Determine the Brinell and the Rockwell hardness numbers.

Brinell = 120,000 × 0.002 = 240; Rockwell = 120,000 × 0.0002 = C24

Example—The hardness of a molybdenum steel No. 4340 is 330 Brinell. Determine its approximate tensile strength.

$$\text{Tensile strength} = \frac{330}{0.002} = 165{,}000 \text{ pounds per square inch.}$$

Hardness Scale. See Mohs's Hardness Scale.

Hardness Testing. See Ballantine Hardness Test; Brinell Hardness Testing; Electromagnetic Hardness Testing; Keep's Test; Pendulum Hardness Tester; Rockwell Hardness Test; Sclerometer; Scleroscope.

Hard Solders. Hard solders, such as are used for silver soldering, and known as *silver solders*, are composed of silver, copper and zinc or brass; whereas hard solders which are used for brazing are alloys formed of copper and zinc. The hard solder used for brazing is commonly known as *spelter* or *spelter-solder*. The composition of silver solders varies considerably according to the nature of the work. A silver solder extensively used by jewelers contains 70 parts of silver and 30 parts of copper.

Hardware Balls. Hardware or C-grade steel balls are balls which may have a slightly defective surface and which are of poorer quality than the steel balls generally used in machine ball bearings.

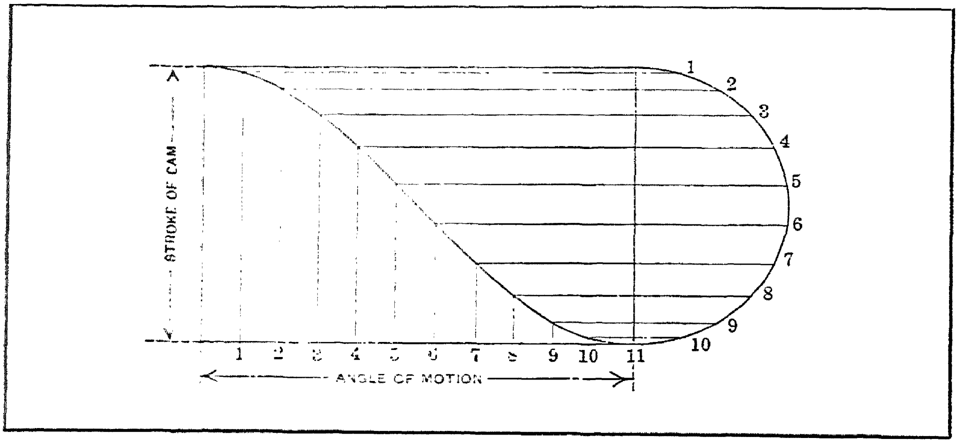
Harmonic. A harmonic is any component of a periodic quantity which is an integral multiple of the fundamental frequency. For example, a component the frequency of which is twice the fundamental frequency is called the second harmonic.

A harmonic, in electricity, is an alternating-current electromotive force wave of higher frequency than the fundamental, and superimposed on the same so as to distort it from a true sine-wave shape. It is caused by the slots, the shape of the pole pieces, and the pulsation of the armature reaction. The third and the fifth harmonics, i.e., with a frequency three and five times the fundamental, are generally the predominating ones in three-phase machines.

Harmonic Motion Curve. The crank or harmonic motion curve works much more easily than the uniform curve, and a cam laid out with this motion may be run at a high speed without much shock or noise. To draw a diagram of this curve, draw a semi-circle having a diameter equal to the stroke of the cam, and divide this semi-circle and the line representing the angle of motion into the same number of equal parts. The intersection of lines drawn from these divisions will give points on the curve. The illustration shows the harmonic curve and the manner in which it is obtained.

Harvey Grip Thread. The characteristic feature of this thread is that one side inclines 44 degrees from a line at right angles to the axis, whereas the other side has an inclination of only 1 degree. This form of thread is sometimes used when there is considerable resistance or pressure in an axial direction and when it is desirable to reduce the radial or bursting pressure on the nut as much as possible. See Buttress Threads.

Harvey Process. In 1891, H. A. Harvey invented a process for making solid steel armor plates. The essential principle of the Harvey process is the subjection of the plates, while they are in contact with finely divided charcoal, to a high temperature for about two weeks. They are then allowed to cool slowly to a dull red heat, and sprayed with water. Plates made by this process have about twice the resisting power of wrought iron. In principle, this is simply a casehardening process applied to unusually large objects: the carbon from the charcoal penetrates the surface of the metal and converts it into high-carbon steel. The depth of the penetration and the amount of the carbon absorbed by the surface of the armor plate increases with the temperature and with the length of time allowed for the process.



Crank or Harmonic Motion Curve

Hastelloy B. Alloy composed of nickel, molybdenum and iron, having a tensile strength in the forged, rolled, and fully annealed state of 135,000 to 140,000 pounds per square inch, with an elongation of 44 per cent in 2 inches. Is also unusually strong at high temperatures, and highly corrosion-resistant. Developed primarily for equipment handling hydrochloric acid in all concentrations and at temperatures up to and including the boiling point; also resists sulphuric, phosphoric, and acetic acids, as well as non-oxidizing acid chloride solutions. Suitable for agitator units, heating and cooling coils, pump parts, pickling tanks, valves, etc.

Haulage Rope. Wire ropes made from six strands of seven wires each are known as "haulage" rope, and also as "transmission" or "standing" rope. This type of rope is not very flexible, and is generally made with large wires, in order to enable it to

resist a great deal of external wear. It is used when the abrasive action is great but when the rope is not required to bend over many sheaves and when the diameter of the sheaves is comparatively large. A greater factor of safety is required in haulage rope than in more flexible rope.

Haveg. A phenol-formaldehyde plastic with unusual acid-resisting properties. Can be used for temperatures up to 265 degrees F.; does not crack when cooled from this high temperature to the freezing point. Suitable in the metal-working industries for constructing or lining pickling tanks. Tanks up to 9 feet in diameter by 9 feet in height have been made from this material in a single piece, without seams or joints.

Header. A header is a large pipe into which one set of boilers is connected by suitable nozzles or tees, or similar large pipes from which a number of smaller ones lead to consuming points. Headers are often used for other purposes—for heaters or in refrigeration work. Headers are essentially branch pipes with many outlets, which are usually parallel. They are largely used for the tubes of water-tube boilers.

Heading Machine. A machine for cold-heading rivets, screw blanks, etc., is called a heading machine or cold-header.

Head or Pressure. The pressure against which a pump forces the water is usually expressed in "feet head." For example, a pump feeding a boiler against a pressure of 100 pounds per square inch is operating under a head of $100 \div 0.433 = 231$ feet; that is, each pound pressure per square inch against which the water is forced is equivalent to lifting a column of water 1 inch square and 2.31 feet high. From the above, it is evident that: Pressure per square inch in pounds $\div$ 0.433 = head in feet; and head in feet $\times$ 0.433 = pressure per square inch in pounds.

In determining the pressure head or total height to which the water must be raised, the distance must be taken from the surface of the water in the reservoir from which it is drawn to the point of discharge. The same power is required to raise water by suction as to force it, and the height of the pump above the water does not enter separately into the calculation at all. This is made plain by a practical example. Assume that a pump is raising water by "suction" 18 feet, and discharging it at this elevation without forcing it at all, all the work being done on the suction side of the piston. When water is raised to this height by suction, the air pressure in the suction pipe is reduced to $14.7 - (18 \times 0.433) = 6.9$ pounds per square inch. This leaves an unbalanced pressure upon the other side of the piston equal to $14.7 - 6.9 = 7.8$ pounds per square inch. The effect is, therefore, the same as if the pump were forcing the water against

this pressure with the water flowing into the cylinder by gravity. To illustrate, take a case where the water flows to the pump by gravity, and is raised to a height of 18 feet. Here the pressure per square inch against which the piston must work is $18 \times 0.433 = 7.8$ pounds, the same as in the preceding case. Hence, it is evident that the work done by the pump is the same whether the water is raised a given distance by suction or forced to the same height by the pressure of the piston.

Friction Head: In what has been said regarding the pressure head required for raising water to a given height, or forcing it against a pressure, as in boiler feeding, no reference has been made to the resistance due to the friction of the water against the sides of the pipes. In computing the required power for operating a pump, and the pipe sizes in a boiler plant where the distances are short, no account is taken of this, but when water is moved long distances through pipes, the friction must be taken into consideration. For convenience in making computations, tables have been prepared giving the frictional resistance for pipes of different diameters and different velocities of flow of water.

Headstock. That part of a lathe and of certain other machine tools, which contains the main spindle with its driving mechanism, is known as the headstock. Some designs of engine lathes have what is commonly referred to as a *friction head.* This is simply a headstock arranged with a friction clutch between the cone-pulley and the large faceplate gear. This clutch serves to connect either the cone-pulley and spindle for the direct drive, or the faceplate gear and spindle when the drive is through back gearing. The clutch is operated by a lever at the front of the headstock. This is a very convenient feature and makes it possible to change to the back-gear drive without stopping the lathe, and enables speed changes to be made much more quickly than with the ordinary design of headstock. Lathes which are commonly referred to by manufacturers as the *geared-head* type, have a headstock which contains a system of gearing so arranged that the drive may be transmitted through different combinations of gearing for varying the spindle speeds. There is either a direct-connected motor or, in case of a belt drive, a single belt pulley instead of a cone-pulley, and the gearing required for obtaining the necessary range of spindle speeds is entirely enclosed. The levers for controlling the clutches by means of which the speeds are varied are located in front of the headstock. The relative positions of the levers for obtaining a given speed are indicated by an index plate.

Headstock Invention. Richard Roberts, a Welshman and one of the first planer builders, invented the back-geared headstock

for lathes about 1818. This headstock design, so far as the arrangement of the cone pulley and back gearing is concerned, is similar to present-day designs of the cone-pulley type. The cone pulley could be disengaged so as to run free on the main spindle, and then the drive was from the cone pinion to the large back-gear and through the pinion on the back-gear shaft to the large gear on the main spindle, as on modern lathes.

Heat. Heat may be defined as the energy in transition or transfer from one body to another because of a temperature difference existing between the bodies. Heat transfer can occur either through conduction or radiation. The wavelength of radiant heat is greater than that of light but less than those wavelengths commonly used for radio transmission. Heat may result from a conversion of mechanical, electrical, or chemical energy.

"Heat-Black" Finish. The so-called "heat-black" finish on brass, copper, or bronze is adapted for a large variety of work. The article to be treated should be free from grease, although a slight tarnish will not affect it. Two stock solutions are first made up. One is a solution of nitrate of copper in water and the other is a solution of nitrate of silver in water. The *nitrate of copper* solution is composed of water, 1 ounce and nitrate of copper, 1 ounce. The *nitrate of silver* solution contains water, 1 ounce and nitrate of silver, 1 ounce. The mixed solution for applying to the metal is made as follows: water, 3 parts; nitrate of copper solution, 2 parts; nitrate of silver solution, 1 part. The solution is kept in a glass or stoneware vessel for use.

The parts to be treated, freed from grease, are heated over a bright charcoal fire, or by means of a gas torch, under a hood, by the side of the tank containing the solution. The solution is kept in a china or stone basin of suitable proportions for the work to be treated; such basin is covered with a wooden cover, and kept under the hood connected with the chimney drawing out the fumes generated, when the parts are dipped in the solution. After the parts have been dipped, they are allowed to drain over the basin for a few seconds, and then heated again until the green froth is burnt and black. If the charcoal fire is used, care must be taken that the wet parts do not touch the coals, as this would cause discolored spots at every point of contact. It will not be detrimental to have the parts laying on the fire when they are dry and green all over. The brushing is made over a tank full of water by means of a wet brush to prevent inhaling the irritating dust. The parts are allowed to dry and afterwards may be finished or they may be smeared with oil, dried in sawdust, and brushed again, or else polished with black lead.

One or two coatings of the solution on the surface of the arti-

cle is usually enough; it dries almost immediately leaving a green froth. The temperature is not sufficiently high to draw the temper of hard brass, but it will usually melt soft solder. When the entire surface has changed to a uniform black color, allow the article to cool and then brush off the fluffy material on the surface of the metal with a stiff-bristled brush. The color will now change to a brownish-black that is quite pleasing for many purposes.

When the smut has been brushed off from the surface of the article, it is immersed in a cold liver of sulphur solution for 5 minutes. The solution is made by dissolving 2 ounces of liver of sulphur in 1 gallon of water. The article is immersed in it, allowed to remain about 5 minutes and then, without rinsing, is again heated until the surface is uniformly black. The surface is now brushed again with the bristle brush when it will be found that the color is a dead black and quite uniform. If the article is lacquered with a flat lacquer or waxed, as may be desired, the final appearance of the surface will be found satisfactory. This is one of the most satisfactory black finishes known, as it is dead black, is readily applied, and very durable.

Heat Coloring. Heat coloring is a method of producing a variety of colors on iron and steel articles by heating them until the desired shade is obtained, and then permitting them to cool off. One method is to heat a flat piece of iron and steel of sufficient size to retain the heat for some time and place the piece to be colored on the hot surface. When the desired color appears, the piece to be colored is plunged into an oil bath. Hot sand or a Bunsen burner may also be used for heat coloring.

Heat Density. The number of British thermal units (B.T.U.) of heat that are in a cubic foot of space under various conditions will be given approximately, assuming 0 degrees F. as a base. On a hot summer day, with the thermometer registering 110 degrees, there is only 1.8 B.T.U. to the cubic foot.

The gasoline blast torch is generally assumed to have a very hot flame, but in the hottest part of that flame the heat density is only 10 B.T.U. per cubic foot. Hydrogen gas, with its enormous heat value, might be expected to have a larger number of units, but in the hottest part of a hydrogen flame burned in the air the B.T.U. per cubic foot are just about 10.1; it has a heat density 1 per cent better than the gasoline flame in air. Carbon burned in air shows a density of 12.3 B.T.U. per cubic foot. Acetylene gas burned in air produces a heat density of 13.1 B.T.U. per cubic foot. Eliminate nitrogen and burn acetylene in oxygen and there are 24 B.T.U. in every cubic foot of the intense flame. Burn hydrogen in oxygen and there are 20 B.T.U. to the cubic foot.

Ordinary steam just as it boils off water into the atmosphere contains 44 B.T.U. to the cubic foot. The oxy-acetylene flame takes a poor second place when compared with steam under these conditions. Superheated steam at 240 pounds per square inch and 300 degrees of superheat, contains over 500 B.T.U. per cubic foot. Strange as it may seem, saturated high-pressure steam at 235 pounds per square inch contains over 650 B.T.U. per cubic foot, and for carrying heat is superior in this respect to superheated steam. A cake of ice at 32 degrees will deliver 937 B.T.U. per cubic foot when cooled down to zero. Boiling water holds over 12,000 B.T.U. per cubic foot.

Melted sulphur, at 800 degrees F., has a heat density about twice that of boiling water, or over 22,000 B.T.U. to the cubic foot. Melted aluminum, at 1214 degrees F., almost doubles this with nearly 43,000 B.T.U. per cubic foot. Melted glass, at 2377 degrees F., has nearly 75,000 B.T.U. in every cubic foot. Platinum, at 3300 degrees F., makes a big jump with its 182,200 B.T.U. per cubic foot. But common melted iron, at 2700 degrees F., leaves platinum away behind with 207,000 B.T.U. per cubic foot. However, they are all surpassed if a cubic foot of carbon is heated almost to its vaporizing temperature, say to 7000 degrees F., as a heat density of 700,000 B.T.U. per cubic foot is then obtained. It is impossible for a person to look at this heated carbon or stand near it, and probably it represents the greatest heat density known. It is found in every arc lamp.

Heat Equivalent of Work. It has been found by experiment that there is a definite relation between heat and work, in the ratio of one British thermal unit to 778 foot-pounds of work. The number 778 is commonly called the *heat equivalent of work* or the *mechanical equivalent of heat.*

A horsepower-hour equals $33,000 \times 60 = 1,980,000$ foot-pounds. The changing of one pound of water at 212 degrees F. into steam at that temperature, will require about 966 British thermal units, or $966 \times 778 = 751,600$ foot-pounds nearly. This being the case, it is evident that the number of pounds of water evaporated at 212 degrees F., which represent one horsepower-hour, equals $1,980,000 \div 751,600 = 2.64$ pounds of water.

Heating Surface of Boilers. The heating surface of a boiler is that portion of the boiler which has one side of the plates or tubes exposed to the hot gases of combustion and the other in contact with the water. In the case of horizontal tubular boilers of the fire-tube type, it is customary to assume that the heating surface is equal to the sum of one-half the shell, two-thirds the rear head less the tube area, and the interior surface of all the tubes.

Heat Insulating Materials. See Insulation, Heat; also Pipe Coverings.

Heat of Evaporation. The heat of evaporation is the total amount of heat required for the changing of water of a given temperature into steam of the same temperature.

Heat Pump. The "heat pump" is an apparatus working on a reversed heat-engine cycle, the object of which is to economize heat in evaporating processes, such as the concentration or the distillation of liquids. In the heat-pump process the vapor from the evaporator is taken to a compressor, in which its pressure, and hence also its temperature, are raised to such a degree that the compressed vapor may serve as the heating medium in the evaporator. It is returned to the heating element of the evaporator accordingly, where it is used for the evaporation of a further amount of liquid. While in certain circumstances a small quantity of live steam may have to be supplied, in general the only energy required in order to carry on the process is that necessary to drive the compressor. The efficiency of the process from the thermal or energy point of view may therefore be measured by comparing the evaporative effect produced with the power expended in driving the compressor. This power may be derived from fuel consumed in the power unit or station from which the compressor is driven, or, of course, from any other source of power, such as water power, and involve no expenditure of fuel at all. Also the compressor may be driven directly by the prime mover or the drive may be indirect, the transmission being effected electrically. The compressor may also take the form of a jet pump supplied from an external source with steam which mixes with the vapor from the evaporator, and is delivered with it to the heating element. The variations of the process are numerous, but all are characterized by the fact that the vapor produced is compressed and returned to the evaporator as the heating medium.

Heat Radiation. See Radiation of Heat.

Heat-Resisting Alloy. See Calite.

Heat, Specific. See Specific Heat.

Heat-Treatment. This term as applied to steel means, according to the S.A.E. definition, an operation or a combination of operations involving the heating and cooling of a metal or an alloy which is in the solid state, for the purpose of obtaining certain desirable conditions or properties. Heating and cooling for the sole purpose of mechanical working is not classified as heat-treatment. Generally speaking, the heat-treatment of steel, includes hardening and tempering of high-carbon steels, casehard-

Table 1. Hardening Carbon Tool Steel

Per cent Carbon	Hardening Temperature, Degrees F.	Quenching Medium	Temperature of Quenching Medium, Degrees F.
0.65 to 0.80	1550 to 1450	Water	70
0.81 to 0.95	1460 to 1410	Water	70
0.96 to 1.10	1390 to 1430	Water	70
1.11 to 1.25	1380 to 1420	Water	70

Table 2. Tempering Carbon Tool Steel

Results Desired	Tempering Medium	Temperature, Degrees F.
Relieving strains	Oil	350 to 375
Relieving strains and reducing brittleness	Oil	400 to 500
Relieving strains and toughening	Oil	500 to 600

ening of low-carbon steels, and annealing of steel. Refer to following sections and also to process or equipment, as, for example, Annealing; Barium-chloride Heating Baths; Casehardening Steel; Carburizing by Rotary Method; Cyanide Hardening; Hardening Steel; Local Hardening; Pack Hardening; Quenching Baths; Tempering.

Heat-Treatment of Carbon Steel. The operations required for heat-treating or hardening plain carbon tool steel are heating, quenching, and tempering. The heating should be done uniformly and Table 1 gives temperatures which may be used as a general guide. From this temperature the steel is quenched in water, but should not be permitted to cool down below the temperature of boiling water (212 degrees F.). The steel may be tempered by being reheated immediately in oil, a salt bath ($NaNO_3$), or in a furnace. Tempering temperatures are given in Table 2.

The quenching temperatures given are at the lowest temperature ranges consistent with high quality tools; deviations are not recommended, but may be necessary in unusual cases. Water is the common quenching medium, and by varying its temperature and manner of application for the abstraction of heat, almost any degree of variation of structural conditions of the tool steel can be obtained. There are, however, special cases where oil may be a more suitable quenching medium; judgment and experience are

the only guides in cases of this kind. The recommended practice for the heat-treatment of tool steel applies to tools for general purposes only. For specific applications, where special requirements seem to be necessary, deviation from the recommended practice must be left to the judgment of the individual heat-treater or metallurgist.

Heat-Treatment of High-Speed Steel. The following directions apply in the heat-treatment of 18 per cent tungsten high-speed steel:

Annealing: Heat slowly and uniformly to a temperature of 1600 degrees F., and hold at that temperature to obtain uniformity of internal condition and grain. Cool in a furnace or in infusorial earth, mica, lime, or any medium that will permit slow, uniform cooling. Cooling in air should not be permitted, since air cooling from the annealing temperature is likely to result in partial hardening of the tool.

Preheating for Hardening: Heat slowly and uniformly to 1600 to 1700 degrees F. in a furnace of sufficient size. The steel should be "soaked" well in preheating to permit even heat penetration. This preheating should be done gradually especially if there are thin and thick sections.

Heating for Quenching: Transfer the preheated steel to a high-temperature furnace which is maintained at a temperature of from 2250 to 2400 degrees F., as a general rule. In order to obtain the most satisfactory "red hardness" conditions, the steel should be brought rapidly to the higher temperature; but in many cases the character of the cutting edges of certain form tools, such as milling cutters, threading tools, etc., makes it inadvisable to use the higher temperatures because of the danger of destroying the delicate edges through blistering, pitting, etc. It is therefore usual to employ the higher temperatures for such tools as rough lathe tools, while the finer class of tools is hardened at the lower temperatures. High-speed steel tools should not be held at the high heat longer than necessary, since holding at the high hardening temperatures causes excessive grain growth, with subsequent brittleness of the hardened tools. Tools that cannot be ground after hardening are often heated in a barium chloride or some similar salt bath.

Quenching High-Speed Steel: Quench the steel in oil which is kept cool by a cold water jacket around the tank or in a salt bath. The quenching tank should be placed close to the hardening furnace, so that the distance from the fire to the oil will be as short as possible. When the tool has cooled below 300 but not below 200 degrees F., transfer it to the tempering medium. High-speed steel tools, especially if of intricate design or requiring exceptional toughness, may be quenched in a bath of molten salt or

lead having a temperature of from 950 to 1200 degrees F. The tool should attain the temperature of the bath before removal, and this usually requires immersion from 15 to 30 minutes. After removal, the tool is allowed to cool in still air to between 200 and 300 degrees F. before placing in the tempering bath.

Tempering or Drawing High-Speed Steel: In tempering, the steel should be allowed to "soak" well until it has attained the full temperature of the furnace and an even heat penetration throughout. Next it should be removed to a dry place that is free from air drafts, and allowed to cool off gradually. Do not quench, as this tends to produce strains in the finished tool that may develop into cracks later under the friction heat of operation. A salt bath is recommended for tempering high-speed steel, although furnaces may also be used. The bath or furnace temperature should be increased gradually, say, from 300 to 400 degrees up to the tempering temperature which may range from 1050 to 1150 degrees F. for high-speed steel or from 1200 to 1300 degrees F. for steels containing cobalt. The temperatures given apply only to lathe, planer, and similar heavy-duty tools that frequently heat up to the point of visible redness while in operation. In general, a tool should be drawn as near as possible to the highest temperature it will attain in actual operation—if above 850 degrees. If it is to be subjected to shocks in operation, a higher draw is necessary. Milling cutters, forming tools, and similar tools for lighter duty, may be drawn at temperatures as low as 850 degrees. Drawing below 850 degrees, however, is not practical, as it leaves the tool too brittle.

Heat-Treatment, Solution and Precipitation Methods. These methods of heat-treatment may be applied to certain non-ferrous alloys such as wrought aluminum and also to some of the magnesium or Dowmetal alloys.

Wrought Aluminum Alloys: The wrought alloys of aluminum may be divided into two classes depending upon the manner in which their harder tempers are produced. One class comprises the alloys in which strain-hardening, by definite amounts of cold work following the last annealing operation, produces the varying degrees of strength and hardness. The alloys in the other class depend primarily upon heat-treatment processes to develop their higher mechanical properties.

While there is a wide range of tensile properties in both classes of alloys, the highest combinations of strength and ductility available in the widest range of products are to be found in the heat-treated alloys. In the aluminum alloys which respond to heat treatment, the alloying constituents which give the increased strength and hardness are substances which are more soluble in solid aluminum at high temperatures than at low temperatures.

Solution Heat-treatment: The first step in heat treatment, frequently called the "solution heat treatment," consists in heating the alloy to a high temperature, below the melting point, to put as much as possible of the alloying constituent into solid solution, then quenching to retain this condition. When in solid solution, the alloying constituent is so finely dispersed that it is not visible with the microscope, even at high magnification. In effect, the alloying constituent has been dissolved in the aluminum and dispersed as completely as when sugar is dissolved in water.

Precipitation Heat-treatment: After quenching, the alloy undergoes an aging process which, if carried out at elevated temperatures, is called a "precipitation heat treatment," because during this stage some of the alloying constituent which is held in solid solution precipitates from the solid solution in the form of extremely fine particles. This precipitation may occur spontaneously at room temperature, as is the case in the so-called "natural aging" of certain alloys, or it may require a "precipitation heat treatment" or "artificial aging" at about 300°F., in the case of certain other alloys.

Heat-treatment of Dowmetal Alloys: Dowmetal castings may be used as cast or in a heat-treated condition. Heat-treatment is not required for general use. However, when increased tensile strength, ductility and toughness are required, without change of yield strength or hardness, castings are "solution heat-treated." This solution heat-treatment is performed in specially designed ovens at temperatures varying from 630 to 785 degrees F., depending upon the alloy, and is followed by air-cooling. Castings so treated are in the best condition for shock resistance. If castings require high yield strength but are not subject to shock, they are solution heat-treated and aged. This aging or "precipitation" is done at about 350 degrees F.

Heat Units. The unit of heat measurement used in English-speaking countries is the British thermal unit (B.T.U.), which is the quantity of heat required to raise the temperature of one pound of pure water one degree F. The French thermal unit, or kilogram-calorie, is the quantity of heat required to raise the temperature of one kilogram of pure water one degree C. One kilogram-calorie equals 3.968 British thermal units, and it also equals 1000 gram-calories. The number of foot-pounds of mechanical energy equivalent to one British thermal unit is called the "mechanical equivalent of heat," and equals 778 foot-pounds. One foot-pound equals 0.001285 heat unit.

Hectograph Composition. This is a compound used as an oil-proof cement, consisting of two parts of good glue or gelatin, one part of glycerin, and seven parts of water, the preparation being applied warm. On cooling it will stiffen quickly.

Hefner Standard. The Hefner standard or unit is the standard of intensity of light as adopted in Germany. The standard intensity of a Hefner is equal to 0.9 international candle, the latter having, since 1909, been established as the national standard for light intensity in Great Britain, France, and the United States. The Hefner standard is the light produced by a wick lamp burning amyl acetate of definitely specific chemical and physical properties, the standard height of flame being 40 millimeters (about 1⅝ inch). The Hefner standard as a unit for the intensity of light is objected to on account of its low intensity, its reddish color, and its sensitiveness to variations in the height of the flame. The element of uncertainty is estimated to almost always exceed 2 per cent.

Hele-Shaw Clutch. This is a clutch devised by Prof. Hele-Shaw. Its principal feature is that power is transmitted through the friction between grooved disks. A number of these disks are placed in the clutch, each disk having a V-groove which fits into the V-groove of the next disk. Every other disk is connected to an outside drum, and the alternating disks, to the shaft to which power is to be transmitted. It has been found that V-shaped disks transmit considerably more power and permit of a more even "pick-up" than clutches with flat disks.

Helical. See Helix Angle; also Spiral and Helix.

Helical Gears. Gears which have a cylindrical pitch surface and teeth which coincide with helical curves on the surface of the pitch cylinder, are known as *helical gears*. Helical gears are also known as "spiral gears," although the teeth are helicoidal like a screw thread and not of spiral form. Various terms are used to designate helical gears. For instance, when helical gearing is used to connect parallel shafts, the term "twisted spur gear" is sometimes used, because the gearing in this case serves the same general purpose as ordinary straight-tooth spur gearing. This relates to the use of single-helical and not the double-helical or "herringbone" gearing. When helical gearing is used to connect shafts located at an angle, the term "helical" or "spiral" is commonly applied, both terms being extensively used. Both of these general classes of gearing have helicoidal teeth, and the principles underlying the methods of cutting them are similar, but the tooth action (when the gears are running together) is quite different, and so also are the functions of the gearing. Thus, when helical gears are used to connect parallel shafts, the object is to secure a smoother action than can be obtained with ordinary spur gears. On the other hand, helical gearing is frequently used as a convenient means of transmitting motion between shafts that are located at an angle and not in the same plane. When parallel

shafts are connected by gearing having both right- and left-hand helical teeth, the terms "herringbone" or "double-helical" gears are commonly used, the former being more common.

Helical Gears, Cutting. Helical gearing is usually cut by some generating method, although milling machines are sometimes used, especially when such gears are not required in quantity. Large helical gears, particularly in the herringbone form, may also be cut on planers of the form-copying type and by the end-milling process. The most common generating method employed is that of hobbing. Gear hobbing machines are very efficient for cutting helical gears, and are widely used for this class of work as well as for spur gears. The general method for cutting helical gears by hobbing is practically the same as cutting spur gears, after the machine is properly geared and adjusted.

Shaping or planing processes of cutting helical gears are used in many shops. The cutter used on a Fellows helical gear shaper resembles a helical gear and has a rotary movement in unison with the gear blank being cut, the principle of operation being similar to that of the shaper for spur gears.

Helical Gears for Angular Drives. Helical gearing for driving shafts which are not intersecting and not parallel is generally considered a rather treacherous type to use, when the amount of power is relatively high. In most installations, the power transmitted is much less than the maximum capacity of the gearing, and whenever the amount of power is likely to be anywhere near the maximum, it is preferable to use worm-gearing, assuming that the angle between the shafts is 90 degrees. If worm-gearing is used, the worm should have as many threads as are required to give the desired velocity ratio. Helical gears that have caused trouble due to abrasion resulting from the small contact area and highly localized pressure, have often been replaced by worm-gearing with satisfactory results. Whenever there is any doubt about the power-transmitting capacity of helical gearing, it is not advisable to rely upon calculations, but to determine this capacity by an actual test under actual running conditions, as regards speed, lubrication, and load.

Helical Gears for Parallel Shafts. Helical gears for parallel shaft drives have several inherent advantages as compared with the spur type. First, the action is distributed over more than one tooth, and all phases of tooth engagement, such as sliding and rolling contact, occur simultaneously, which tends to equalize wear and preserve the correct tooth shape. The load is transferred gradually and uniformly as successive teeth come into engagement, and the bending action resulting from the tooth load

is less than for a spur gear, because the line of contact extends diagonally across the meshing teeth; the tooth load of a helical gear, however, is higher because of the angular position of the teeth, and the normal tooth section is, of course, smaller than that of a spur gear of the same circular pitch.

Three Classes of Problems: Helical gear designing problems for parallel-shaft drives may be divided into three very general classes. In considering these three classes or cases, reference to diametral pitch will be made by way of illustration, but the same principle would apply if the gear were designed on the basis of circular pitch.

Case 1: When a special helical gear hob or cutter is used having some standard diametral pitch in the plane of rotation: Such a hob or cutter is special in that the tooth thickness is reduced an amount depending upon the helix angle, thus making the circular pitch of the gear in the plane of rotation equivalent to a standard diametral pitch.

Case 2: When a standard spur-gear hob is used because a special helical gear hob is not available: In this case the diametral pitch of the hob represents the normal diametral pitch of the gear and the diametral pitch in the plane of rotation will be an odd fractional pitch unless the pitch in the plane of rotation is also made standard, as explained in the next paragraph.

Case 3: When a standard spur-gear hob or cutter is used and a special helix angle is selected to make the diametral pitch in the plane of rotation standard as when spur gears are to be replaced by herringbone or single-helical gears without changing the center distances between the shafts or the ratio.

Replacing Spur Gears with Helical Gears: When spur gears on some existing machine are to be replaced either by single-helical or double-helical (herringbone) gears and both center distance and ratio must be retained, it may be possible to cut the helical or herringbone gear with a hob or cutter of standard pitch by making the helix angle special.

RULE: Select a hob or cutter having a diametral pitch equivalent to a slightly smaller tooth than that of the spur gearing to be replaced. Divide diametral pitch of spur gearing by diametral pitch of hob selected, thus obtaining cosine of helix angle required.

EXAMPLE 1: A machine has shafts connected by spur gears having 30 and 90 teeth, respectively, of 6 diametral pitch. Determine pitch of hob and helix angle of helical or herringbone gears to replace spur gears. If a spur-gear hob of 7 diametral pitch is used,

$$\text{Cos special helix angle} = \frac{6}{7} = 0.85714$$

Hence helix angle equals 31 degrees, and with this angle the diametral pitch in the plane of rotation will be 6, like the spur gears which are to be replaced.

EXAMPLE 2: The spur gears, Example 1, are to be replaced by herringbone gears and a hob of 4 module (metric) is available. Determine helix angle.

The equivalent diametral pitch equals $25.4 \div 4 = 6.35$; hence

$$\text{Cos special helix angle} = \frac{6}{6.35} = 0.94488$$

The equivalent angle is 19° 7′ and the diametral pitch in the plane of rotation is 6, as required.

Helical Gears, Helix Angles and End Thrust. The selection of an angle for parallel shaft drives may depend to some extent upon the allowable end thrust, as, for example, in cases where a certain amount of end thrust would be tolerated in order to use a larger angle and obtain smoother tooth action. In many helical-gear transmissions for parallel-shaft drives, it is customary to use fairly small helix angles. Often an angle as small as 7 degrees is used; 12 degrees is favored by some designers; and either 23 or 30 degrees is customarily used for double-helical or herringbone gears.

In automotive practice, angles up to 45 degrees and even larger are used. The angles of the helical gears used in automotive transmissions were increased in order to obtain quieter gearing. However, tests have shown that it is not necessary to use as steep helix angles as have been employed to obtain the best results. In theory, the steeper the angle, the quieter should be the gears, because of the tooth overlap; but this is true only of perfect gears, which cannot be produced, especially in regular production work. Generally speaking, the helix angles of transmission second-speed gears in use at the present time range from 25 to 45 degrees. Many designers at the present time prefer angles between 30 and 40 degrees.

Tests were made to determine, if possible, just what angle should be used to obtain the greatest degree of quietness for the second-speed gears in a transmission. Sets of gears, beginning with spur gears and ending with 45-degree helical gears, were cut and lapped as nearly perfect as possible. All the gears were cut with the same hob and finished with the same lap, after which they were thoroughly inspected. The pinion and drive gear were in a 2 to 1 ratio, the helix varied by 5-degree increments from spur gear (0 degree) to 45 degrees. An adjustable-center-distance case was used. The general results of the tests were that the noise decreased until a 20-degree angle was reached, but, from that point on, there was no noticeable improvement.

End Thrust: In order to determine the end thrust of helical gearing as applied to parallel-shaft drives, first calculate the tangential load on the gear teeth. If the amount of power to be transmitted is 7 horsepower and the pitch-line velocity 200 feet per minute, the tangential load will equal $33{,}000 \times 7 \div 200 =$ 1155 pounds. The axial or end thrust may now be determined approximately by multiplying the tangential load by the tangent of the tooth angle. Thus, in this instance, the thrust $= 1155 \times \tan$ 15 degrees $=$ about 310 pounds. The end thrust obtained by this calculation will be somewhat greater than the actual end thrust, because frictional losses in the shaft bearings, etc., have not been taken into account, although a test on a helical gear set, with a motor drive, showed that the actual thrust of the 7½-degree helical gears tested, was not much below the theoretical values.

The ratio between peripheral tooth pressure and resultant thrust was determined by measurements taken while the gearing was in operation under various loads. The tangential tooth pressure was determined in the usual way from observed revolutions per minute and wattage. Corrections of horsepower were made from an efficiency chart of the motor. The thrust was measured by applying a graduated spring balance against the end of the motor shaft with sufficient pressure to balance the thrust and move the shaft away from the face of the bearing. As there was over ¼ inch end play between the bearings, it was easy to tell when the thrust surfaces were separated. This test showed conclusively that the thrust developed by helical gearing was practically proportional to the tangent of the helical angle.

Helical Gear Terms and Dimensions. The diagram illustrates a helical gear (see Fig. 1). The teeth have a helix or tooth angle a. This angle is measured from the axis, as the diagram shows, and it represents the inclination at the pitch diameter.

The sum of the helix or tooth angles of a pair of mating helical gears is equal to the shaft angle or angle between the shaft axes.

Pitch Diameter: The number of teeth and the pitch diameter are terms which are identically the same as those used for spur gearing.

To find the pitch diameter of a helical gear, divide the number of teeth by the product of the normal diametral pitch and the cosine of the tooth angle.

Diametral Pitch: Practically all helical gears are made to the diametral pitch rather than the circular pitch system. The regular diametral pitch of a helical gear will be found, the same as for a spur gear, by dividing the number of teeth by the pitch diameter in inches. It is not necessary to know what this is, however, since it does not enter into the calculations, and since the cutter used has to be for a somewhat finer diametral pitch. This is shown

by the diagram. The normal diametral pitch, or diametral pitch of the cutter used, is reckoned from measurements taken along the pitch cylinder at right angles to the length of the tooth. P' represents the regular circular pitch, while P'_n represents the normal circular pitch. The normal diametral pitch may be found by dividing 3.1416 by P'_n. It may also be found by dividing the number of teeth by the product of the pitch diameter D and the cosine of helix angle a. This is the pitch of the cutter to be used.

Shaft Angle: The shaft angle of a pair of helical or spiral gears is the angle made by the two center lines or axes of the

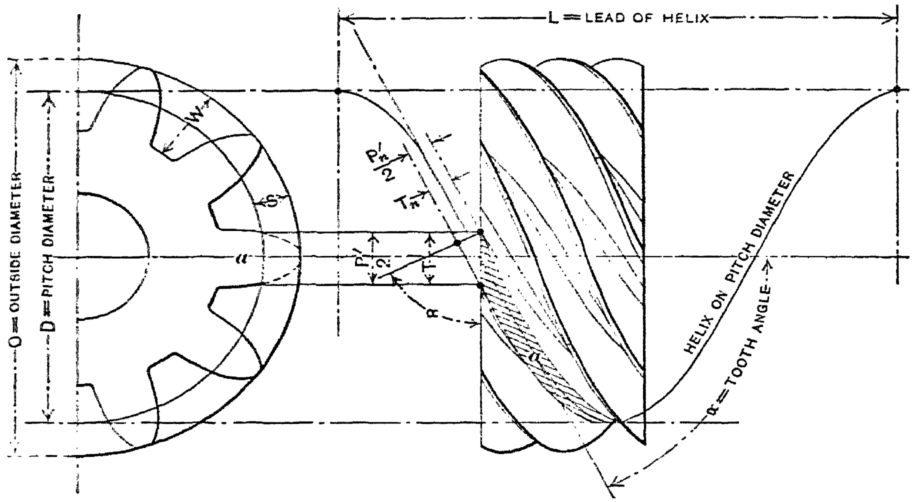


Fig. 1. Diagram of Helical Gear Illustrating Terms used in the Calculations

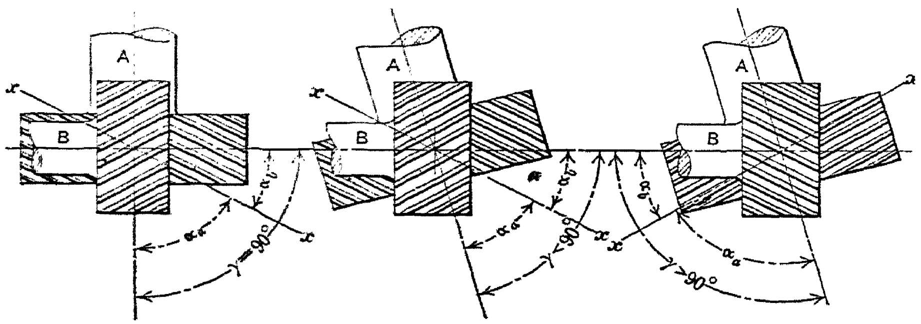


Fig. 2. Helical Gears with Different Shaft Angles

gears, as taken in a view perpendicular to both axes. The diagram, Fig. 2, shows three sets of helical gears taken in the plane which shows the shaft angles. At the left is the ordinary case in which the shafts are at right angles with each other, so that the angle (γ) is 90 degrees. In the second case, γ is less than 90 degrees, and in the example shown at the right, it is more. It should be noted in the last two cases that the position of the shaft axes is identical, but that the two shaft angles are located on opposite sides of axis *A*. In order to know on which side of the center line to take the center angle in cases like those shown, the position of the teeth of the gears in contact must be considered. The center angle is taken at the side which includes the line *x–x*, passing lengthwise of the teeth of the gears at the point of contact with each other. Since the teeth are laid out differently in the two cases, the angles are different. The case shown in the center is the more usual of the two, the other being very rare.

Helium. Helium is one of the lightest of the gases, although not so light as hydrogen, its specific gravity, compared with air as a unit, being 0.138. Helium is present in small quantities in the atmosphere, and also in many minerals. It is contained almost universally in the gases in the water of thermal springs. It does not enter into a chemical combination with any other chemical element, but is always mechanically mixed or contained in the substance in which it is found. Helium becomes liquid at a temperature of only a few degrees above the absolute zero, and becomes solid at a temperature only two degrees below that at which it liquefies, these temperatures being around —267 degrees C. (—449 degrees F.). According to laboratory experiments at the University of Leyden, Holland, it appears that at absolute zero a pressure of about 16 atmospheres would be required to solidify helium. The actual solidification took place at a temperature about 2.2 degrees C. above absolute zero at a pressure of 50 atmospheres, and at 4.2 degrees C. above absolute zero at a pressure of 140 atmospheres. Solid helium forms a homogeneous transparent mass which differs to an extremely small extent from the appearance of liquid helium.

Helix. A helix is a curve in three dimensions; that is, it is not a curve situated in one plane. Examples of this curve are found in the helical spring, the helical or spiral gear, and the ordinary screw thread. In a sharp V screw thread, for example, the line forming the top of the thread forms a helix. The distance between the various convolutions of the helix, measured parallel to its axis, is known as its *lead.* Helices are often, although incorrectly, referred to as *spirals.* A spiral, however, is a curve situated in one plane and is exemplified by an ordinary watch

spring having consecutive layers or convolutions extending outward.

Helix Angle. If the base of a right-angle triangle equals the lead of a screw thread and if the altitude equals the pitch circumference of the screw, then the angle between the hypotenuse and altitude of the triangle equals the helix angle of that screw thread at the pitch line; hence, the tangent of the helix angle equals the lead of the thread divided by the pitch circumference (circumference at one-half the thread depth). It is evident from the foregoing that the helix angle of a screw thread is measured from a plane perpendicular to the screw axis and it is usually known as the *lead angle.* This angle ordinarily is based upon the pitch diameter. If the helix angle at the top of a screw thread were required, the circumference at the outside diameter would be taken instead of the pitch circumference.

The helix angle of a helical (spiral) gear is measured from the axis. Thus if the lead (axial distance that a tooth would advance if it made one complete turn) of a helical gear equals the base of a right-angle triangle and if the pitch circumference of the gear equals the altitude, then the angle between the hypotenuse and the base equals the helix angle; hence, the tangent of this helix angle equals the pitch circumference of the gear divided by the lead of the helix.

Helve Hammers. The power hammer commonly known as a *helve* hammer, is so named because the upper hammer die is attached to the end of a wooden helve. The hammer of a typical design is driven by a belt operating on a pulley and on the shaft which carries this pulley there is an eccentric which, by means of a suitable strap and connecting-rod, operates a lever or arm which, in turn, actuates the hammer helve; motion is imparted to the helve through rubber cushions which impart "snap" and elasticity to the blow. The wooden helve is hung upon hardened steel centers and may be adjusted to accommodate variations either in the thickness of the die or of the stock that is to be forged. The hammer is controlled by a foot-treadle which extends around the side and front of the hammer base. Helve hammers are made in several different designs which differ either in regard to the method of imparting motion to the helve or in the arrangement of the hammer die. Hammers of the helve class are especially adapted for comparatively light forging operations which require a succession of rapid blows, and they are extensively used for drawing out stock and, in some cases, special dies are employed for producing duplicate forgings of uniform shape and size.

Hematite Ore. Hematite ore, also frequently known as "red hematite," is an iron oxide of the composition Fe_2O_3, containing

about 70 per cent of iron. Most of the iron ores mined in the United States belong to this class. The color of hematite varies from a bluish gray to a deep red, but it always gives a red streak on a porcelain plate. The hardness of hematite varies from 5.5 to 6.5 on the Mohs scale. The specific gravity varies from 4.2 to 5.3. Hematite is an anhydrous oxide containing no water in combination after having been heated to a temperature of 212 degrees F. See Iron in Iron Ore; also Magnetite.

Hemp Rope. The fiber of the hemp plant is used for making hemp rope. Hemp rope is not so strong as Manila rope of the same size. A hemp rope, if dry and untarred, will break from its own weight, at a length of about 2800 feet. If wet and tarred, it will break from its own weight at about 2000 feet. Sometimes, when the depths at which ropes are used are very great, they are given approximately the form of a body of uniform strength, by making them of separate pieces, the diameters of which diminish toward the lower end. In this way, the stresses in the fibers due to the rope's own weight can be considerably decreased.

Henry. The unit of inductance is called the *henry*, which is the inductance of a coil in which a current varying at the rate of one ampere per second will induce one volt. The one volt induced does not include the electromotive force necessary to overcome the resistance of the circuit. As this unit is too large for practical purposes, the *millihenry* (one thousandth of a henry) is the unit used in rating coils and electromagnets.

Heptagon. Any plane figure or surface bounded by seven straight lines is called a *heptagon.* If all of the sides are of equal length and the angles between the sides are equal, the figure is called a *regular* heptagon.

Hermaphrodite Caliper. A caliper provided with one straight pointed leg similar to that of a divider, and one leg with a bent end similar to that of an ordinary machinist's inside caliper is known as a hermaphrodite caliper. Calipers of this type are used in laying off distances from the edge of a piece of work and for locating the center of round work.

Herringbone Gears. Helical gears are often used for parallel-shaft drives because of the smooth continuous action. Single helical gears, or a right-hand gear on one shaft meshing with a left-hand gear on the other shaft, may result in excessive end thrust. End thrust may be avoided by placing on each shaft two helical gears side by side, having teeth cut in opposite directions. This type of gearing has been termed "herringbone" gearing. Herringbone gears may be formed of two half sections or of one solid piece. When there are two sections these may be cut

separately, the same as two single-helical gears, and afterward bolted together so that the teeth of each section are either in alignment or staggered, as may be required. If herringbone gears are made of one solid piece, the right- and left-hand teeth may also be directly opposite or be offset an amount equal to one-half the circular pitch. Solid gears have a central clearance space between the right- and left-hand tooth sections when necessary to provide room for the cutter or hob, the amount of clearance required varying for different methods of cutting; the method may be such that the clearance space is eliminated entirely, the teeth extending across the gear without a groove at the center.

With herringbone gearing the bending stress on the teeth does not fluctuate from maximum to minimum, as in straight gears, but remains always near the mean value. This feature is of especial importance in rolling-mill driving and work of a similar nature. Herringbone gears are especially applicable for high velocities and ratios in connection with turbine reduction gearing or for installations requiring a minimum of vibration and noise. Accurate and well-made herringbone gears are often operated at pitch-line velocities of from 3000 to 5000 feet per minute in connection with steam turbine reduction gearing, and the ratios may be 10 to 1 or higher for some installations.

Double helical or herringbone gears may be produced either by hobbing, planing (using either a gear shaper or planer) or milling. In hobbing gears of this type, an ordinary machine designed for cutting spur and helical gears may be used, or the work may be done on a special machine intended particularly for herringbone gears. If the planing process is employed, the teeth may be formed by a generating method, or a machine of the templet or form-copying type may be used.

Wuest Herringbone Gears: The teeth of the Wuest gears are so designed that those on the right- and left-hand sides of the gears are stepped half a space apart and do not meet at a common apex at the center of the face, as in the usual type of herringbone gear. The stepped form will wear more evenly under extreme loads than the ordinary type.

Hexavalent. This term is used to indicate that an atom of one element will combine with six atoms of another element. It is also known as sexivalent.

High Brass. What is known as "high brass" is especially suitable for cold rolling and drawing; it contains from 30 to 40 per cent of zinc, the remainder being copper. If there is over 0.1 per cent of lead, the ductility of the brass is decreased and for this reason sheet brass intended for drawing purposes should be as free from lead as possible.

High-Cycle Portable Tools. The term "high-cycle portable tools" is a trade designation for portable electric drills, grinders, sanders, polishers, nut-setters, etc., operated by a 180-cycle, three-phase, alternating current. As the available electrical power is generally either direct current or 60-cycle alternating current, the desired 180-cycle current is obtained from these sources by a motor-generator or a frequency converter. The main purpose of the development of high-cycle tools was to utilize the simplicity of the three-phase induction motor, with its indestructible rotating element, and to eliminate commutators and brushes, which are a source of considerable maintenance expense in universal motors. With the customary 60-cycle power supply of 60 cycles per second, the speed of the rotating element is limited to 60 revolutions per second, or 3600 revolutions per minute, which is changed to desired speeds for drilling or other operations by suitable gearing. With this low rotating-element speed, it was not possible to obtain the desired light weight of portable tools, combined with the degree of robustness and reserve power required, and, consequently, the number of cycles was increased to three times that of the customary 60, or 180 cycles, giving a speed of the rotating element of 10,800 R.P.M., which is comparable with universal tool speeds.

High-Frequency Induction Motors. Induction motors designed to operate at a speed greater than 3600 revolutions per minute (the maximum for squirrel-cage and wound-rotor motors with two poles, operating at 60 cycles) are called high-frequency motors because their operation is based on utilizing a high-frequency power supply. They are used in portable drills and woodworking machinery where small compact units of comparatively high horsepower are desired.

These motors are of the same construction as the standard squirrel-cage motors and their speeds range from 3600 to 18,000 revolutions per minute. Higher speeds are feasible if required commercially.

According to the National Electrical Manufacturers Association, the standard frequencies for these motors as used in portable hand tool applications is 180 cycles at 110 and 220 volts, and for motors as used in the woodworking industry or for general-purpose applications is 60 cycles and 120 cycles at 220 volts. At any other frequency the voltage will be in proportion to the frequency. The ratings of these motors are based on a continuous duty with a temperature rise of 40 deg. C.

Probably the majority of motors used in the machine tool industry are of the two-, four-, six-, or eight-pole type. The synchronous speed of an alternating-current motor is obtained by dividing the number of alternations per minute by the number of

poles. For example, consider a two-pole motor operating on a 60-cycle circuit. Sixty cycles is equivalent to 7200 alternations per minute, and dividing this number by 2, the motor speed is found to be 3600 revolutions per minute. Since a motor cannot have less than two poles, 3600 revolutions per minute is the maximum speed that can be obtained on a 60-cycle source of supply. In order to obtain the higher speeds, it is necessary to increase the frequency or the number of cycles per second.

High-Speed Steel. The expression "high-speed steel" is derived from the fact that such steel is capable of cutting metal at a much higher rate of speed than ordinary carbon tool steels. The reason why high-speed steel can be used at higher speeds is that it has a special property known as "red hardness," or, in other words, this steel is able to retain its hardness even when heated to a dull red; hence, when cutting at a high rate of speed, the steel, although it becomes heated to a degree which would make an ordinary tool steel useless, retains its cutting qualities. A high-speed steel is not necessarily one conforming to any given analysis but it is some kind of alloy steel. Most high-speed steels contain tungsten as the chief alloying element, but other elements, such as molybdenum, confer the red-hardness characteristic. A high-speed steel should continue to cut when the point of the tool becomes heated to a dull red temperature because of the red-hardness characteristic conferred upon it by tungsten, molybdenum or other alloys. The reason why high-speed steels in general can be heated considerably as the result of high cutting speeds and excessive friction is that some element (or combination of elements), such, for example, as tungsten, so changes the characteristics of the steel that the increase of temperature does not affect it, the same as with ordinary carbon steel.

While high-speed steel is valuable for metal-cutting tools because it will retain a cutting edge even at high temperatures, it is also used for many purposes where temperature is not a factor. This is true, for example, in the case of blanking dies, broaches, certain types of shear blades, etc. High-speed steel in the hardened condition has from five to eight times the wear resistance of a 1 per cent hardened carbon tool steel at ordinary room temperature.

High-Speed Steel Compositions. There are many different compositions for high-speed steels but the 18-4-1 steels, which contain 18 per cent tungsten, 4 per cent chromium, and 1 per cent vanadium, may be classed as the standard tool steels. This type is a very satisfactory general-purpose steel, as it can be easily forged, is relatively insensitive to variations in heat-treatment, and possesses considerable physical strength in addition to a high red-hardness. A steel of this analysis is used for most of the

high-speed steel tools that are bought in a completed condition, such as drills, taps, and milling cutters. It is of particular value in that it is applicable to practically all machine shop operations.

The exact composition of these 18-4-1 tungsten steels varies somewhat. For example, the tungsten content may range from 17 to 21, the chromium from 3 to 4½, and the vanadium from 0.7 to 1½. High-speed steels of this general type are easier to harden than some of the other compositions, and they have proved very satisfactory for cutting various materials under normal conditions. The 18-4-1 steel is not only used extensively for forged lathe and planer tools, but for milling cutters, drills, reamers, taps, threading dies, punches, and sheet metal dies, etc.

The 14-4-2 Type: Another general class of tungsten high-speed steel is known as the 14-4-2 type. This is sometimes preferred for heavy roughing cuts, but is not used as much today as formerly. Because of the lower tungsten content of 14 per cent, this steel is more sensitive to heat-treatment. The carbon content of the various classes of tungsten high-speed steels ranges from about 0.60 to 0.80 per cent. The usual carbon content is from 0.67 to 0.72, as this range gives the best combination of hardness, toughness, and cutting capacity. For a given tungsten and chromium content, the hardness and toughness varies in direct proportion to the carbon content.

Some turning tools are made from an 18-4-2 or "double-vanadium" type of high-speed steel. When applied to broaching, the 18-4-2 steel has proved superior to the 18-4-1 type.

Cobalt Steels: The high-cobalt or cobalt-tungsten steel is adapted to heavy roughing cuts. These cobalt steels are similar to the 18-4-1 tungsten steel with a certain amount of cobalt added. The high-cobalt tungsten steels contain usually from 7.5 to 12 per cent of cobalt. Tools made of this steel should not be forced to their maximum cutting capacity until the temperature has been raised by the cutting action. With the possible exception of small tools, high-cobalt steel should not be forged because it is more difficult to forge than the high-tungsten steel. As cobalt steels are more expensive than ordinary high-speed steel, it is common practice to weld or braze cobalt-steel tips to a cheaper grade of steel which is used for the shank.

Low-cobalt Steel: A low-cobalt high-speed steel has proved very satisfactory for finishing tools requiring tough hard edges. The cobalt type is superior to high-tungsten steel in withstanding relatively high temperatures and maintaining a sharp cutting edge when taking long finishing cuts. This is one reason why cobalt steel is specially adapted for tools used on automatic screw machines or wherever tool replacement involves some difficulty and long tool life is particularly important. A low-cobalt steel

may contain from 4½ to 5 per cent of cobalt, 17 to 18 per cent tungsten, and 0.90 to 1.10 per cent vanadium.

Steels for Drills: Manufacturers of twist drills generally use practically the same analysis of high-speed steel. This analysis is approximately as follows: Carbon, 0.70; tungsten, 18; chromium, 4; and vanadium, 1 per cent. Steels with somewhat over 0.70 per cent carbon are generally used for small drills, while slightly less than 0.70 per cent carbon is used for the larger sizes. The 14 per cent tungsten high-speed steel is no longer used for drills. High-speed steel containing no tungsten, but instead approximately 7 per cent of molybdenum, has given very good results.

Cobalt high-speed steel drills find wide application in drilling hard metals which are beyond the capacity of ordinary high-speed drills. In resisting the action of abrasion, the cobalt high-speed steel drills, with their higher carbon and alloy content, are superior to those made from ordinary high-speed steel, but they cannot be compared with tungsten-carbide tipped tools. The addition of cobalt to high-speed steel increases the "red hardness." In other words, cobalt high-speed steel drills can be subjected to higher cutting temperatures without destroying the edges.

High-Speed Steel, Super. The term "super high-speed steel" is applied to high-cobalt steels which are especially adapted to heavy-duty roughing operations. See Cobalt Steels under High-speed Steel Compositions.

High-Speed Steel, Tungstenless. See Cobaltcrom Steel.

Hindley Worm Gearing. Worm gearing of the Hindley type is generally supposed to have been originated by Henry Hindley, a noted clockmaker in York, England. There is no record of the year in which the Hindley worm gear was first made, but it was used in a dividing engine and described in a paper presented to the Royal Society by John Smeaton in 1785. In 1741 Smeaton had been shown a dividing engine containing this gearing. Hindley was also the inventor of the Hindley dividing engine, which was one of the first devices for accurately dividing a circle into a given number of equal parts.

Hindley worm-gearing or "globoid" gearing differs from ordinary worm-gearing in that the worm is curved in a lengthwise direction to fit the worm-gear, instead of being cylindrical. The idea is to so shape the worm that it will make contact throughout its length with the worm-gear, instead of engaging the gear along the mid-section only. Although perfect surface contact over all the teeth in mesh is not obtained, the contact is doubtless of a superior nature in well-constructed Hindley gearing. The exact nature and extent of the contact, however, is uncertain,

owing to the fact that the theoretical contact does not agree with the results actually obtained by commercial manufacturing methods, which alter to some extent the theoretical form.

Hobbing Die Impressions. This method is designated as hobbing or hubbing, because a "hob" or "hub" is used, which is in the form of a punch and has a shape corresponding to the impression required in the die. See Hub Method of Die-sinking.

Hobbing Process. Gear teeth cut by the hobbing process are given the required shape or curvature by a generating action resulting from the rotation of the gear blank relative to a cutter of the hob form. Gear-hobbing machines are commonly applied to the cutting of spur, helical, and worm gearing, and hobbing is the most rapid method of cutting gears by a generating process. In the practical application of the generating principle to gear-hobbing machines, the hob used has cutting teeth of the same cross-sectional shape as teeth of a rack of corresponding pitch, except for minor variations such, for example, as increasing the length of the hob teeth to provide for clearance at the bottom of the tooth spaces. As the hob teeth lie along a helical path (like a screw thread) the hob is set at an angle to align the teeth on the cutting side with the axis of the gear blank. When the hob is inclined an amount depending upon the helix angle of its teeth, the latter, on the cutting side, represent a rack.

When a hobbing machine is in operation, the gear blank and hob revolve together, the ratio depending upon the number of teeth in the gear and the number of threads on the hob—that is, whether the hob has a single or a multiple thread. This rotation of the hob causes successive teeth to occupy positions corresponding to the teeth of a rack, assuming that the latter were in mesh with the revolving gear and moving tangentially. In conjunction with the rotary movement of the hob, the slide on which it is carried is given a feeding movement parallel to the axis of the gear blank. As this feeding movement continues across the gear blank (or blanks when several are cut together) all of the gear teeth are completely formed; thus hobbing is a continuous operation, since the teeth around the entire circumference of the gear are finished together (instead of one tooth being cut at a time) and ordinarily by one passage of the hob.

Hob "End Angle." The angle at which the hob-spindle or swivel slide is set depends upon the lead of the hob thread and its diameter, since the object of inclining the hob is to bring the teeth on the cutting side into alignment with the axis of the gear blank. This angle is equal to the helix angle of the hob thread at the pitch-line, measured from a plane perpendicular to the hob axis, and is often called the "end angle." To avoid the

necessity of making calculations, this angle is usually stamped on the hob. If the angle is not known, its tangent may be determined simply by dividing the lead of the hob thread by the pitch circumference.

Hob Flutes. If a hob is to be used in a gear-hobbing machine in which the hob and blank are positively geared together, the number of flutes may be comparatively small as compared with a hob that is to be used for hobbing worm-gears in a milling machine. A rule that agrees well with present practice is as follows: *To find the number of flutes in a hob, multiply the diameter of the hob by three, and divide by twice the circular pitch.* This rule gives approximate results on hobs for general purposes. In addition, the following considerations must be taken into account. Some authorities on worm gearing state that the number of flutes in a hob should in no case be an exact multiple of the number of threads. Their reason for this rule is that the hob so gashed will produce a much smoother tooth and one nearer correct in shape, because no tooth in the hob passes the same tooth in the gear twice in succession, so that any imperfections in the shape of the individual hob teeth are counteracted by one another. According to another authority, the circumferential distance from flute to flute should not be equal to or equally divisible by the circular pitch, for the same reason as stated regarding the former rule. From the foregoing statements, it is seen that to obtain a rule that would be at once simple and yet take all conditions into consideration, would be difficult.

It is important that the number of flutes or gashes in hobs bear a certain relation to the number of threads in the hob and the number of teeth in the worm-wheel to be hobbed. Avoid having a common factor between the number of threads in the hob and the number of flutes; that is, if the worm is double-threaded, the number of gashes should be, say, 7 or 9, rather than 8. If it is triple-threaded, the number of gashes should be 7 or 11, rather than 6 or 9. The second requirement is to avoid having a common factor between the number of threads in the hob and the number of teeth in the worm-wheel. For example, if the number of teeth in the wheel is 28, it would be best to have the hob triple-threaded, as 3 is not a factor of 28. Again, if there were to be 36 threads in the worm-gear, it would be preferable to have 5 threads in the hob. It is desirable that hobs should be fluted at right angles to the direction of the thread. Sometimes, however, it is necessary to modify this requirement to a slight degree, because the hobs cannot be relieved unless the number of teeth in one revolution, along the thread helix, is such that the relieving attachment can be properly geared to suit it.

Hob Method of Die-Sinking. See Hub Method of Die-sinking.

Hobs, Multiple-Threaded. In cutting spur gears by the hobbing process, double- or even triple-threaded hobs are sometimes used instead of a single-threaded hob. A multiple-threaded hob will reduce the actual cutting time in direct proportion to the number of threads, as compared with a single-threaded hob of equal size, having the same speed and feed. A single-threaded hob, however, generates more accurate teeth, and it is the type commonly used. The reason that a hob having a double or triple thread reduces the cutting time in proportion to the number of threads will be evident by considering a specific example.

Assume that the gear to be hobbed has forty teeth, the hob feed per gear revolution is 0.1 inch, the total hob travel 2 inches, and the hob speed 100 revolutions per minute. In using a single-threaded hob, the gear will revolve 20 times while the teeth are being cut, since $2 \div 0.1 = 20$; hence, the hob makes $20 \times 40 = 800$ revolutions while traveling 2 inches, and as the hob speed is 100 revolutions per minute, the actual cutting time equals $800 \div 100 = 8$ minutes.

Assume now that the same gear is to be cut with a double-threaded hob. If the feed is still 0.1 inch per gear revolution, 20 gear revolutions will be required for a total hob travel of 2 inches as before. The hob, however, makes 20 revolutions to one of the gear, instead of 40, as with the single-threaded hob. Since the double-threaded hob also rotates 100 revolutions per minute, the gear will have a speed of $100 \div 20 = 5$ revolutions per minute, instead of $100 \div 40 = 2\frac{1}{2}$ revolutions per minute, as for single-threaded hob; consequently, if the double-threaded hob feed is 1/10 inch per gear revolution, it moves $1/10 \times 5 = 5/10$ inch per minute, and it travels the required 2 inches in $2 \div 0.5 = 4$ minutes. This time, as will be seen, is one-half that required for a single-threaded hob, because the gear blank rotates at twice the speed when using a double-threaded hob.

If a similar comparison were made between a single-threaded and a triple-threaded hob, it would be found that the latter would require only one-third the cutting time needed for a single-threaded hob. The triple-threaded form is sometimes used for cast-iron gears which do not need to be very accurate. When multiple-threaded hobs are used for steel gears, ordinarily the double-threaded form is employed.

Hobs, Spline Shafts. The usual method of determining the form of the hob for straight-sided spline shafts is to roll the particular spline shaft as a gear, and thus develop the form of its corresponding basic rack. This is done on the drawing board, with the spline shaft suitably enlarged. The first problem to be solved is the position or size of the pitch circle for the spline. If it is too large, a troublesome fillet will be produced at the

bottom of the spline. If it is too small, the top of the face of the spline will be rounded or beveled off.

When the splines are of involute form, the hob teeth have straight sides inclined to the desired "pressure angle" which, according to the American Standard, is 30 degrees. These hobs for involute splines are, of course, easier to make than hobs for the straight parallel-sided splines. The latter may be designed by the mathematical method which follows:

Establishing Hob Curvature Mathematically: When a calculating machine is available, the forms for the cutting edges of these hobs may be established analytically, to any degree of accuracy desired, in much less time than is required to obtain the same results, to a lesser degree of accuracy, by a geometrical lay-out.

The following method and calculations for determining the form of the teeth of hobs for spline shafts is from Earle Buckingham, Professor of Mechanical Engineering, Massachusetts Institute of Technology.

Referring to Fig. 1:

A = half thickness of spline;
R = pitch radius of spline;
y = ordinate of line of action and hob profile;
X = abscissa of line of action;
x = abscissa of hob profile; and
E = angle of rotation (chosen arbitrarily).

Then,

$$\text{Cos } B = \frac{A}{R};\ D = B - E$$

$$y = \cos D\ (R \cos D - A)$$

$$X = \sin D\ (R \cos D - A)$$

$$x = R \text{ arc } E - X$$

As an example, take the S A E 1½-inch, ten-spline shaft. Use the outside radius as the pitch radius. This gives the following values:

$$A = 0.115;\ R = 0.750$$

Then,

$$\text{Cos } B = \frac{0.115}{0.750} = 0.15333 \text{ and}$$

$$B = 81 \text{ degrees, } 10 \text{ minutes, } 48 \text{ seconds}$$

Select successive values of E varying by 3 degrees. The calculations are shown in the accompanying table. The coordinates x and y of the hob tooth profile may be plotted to any enlarged scale desired, say 100 times the size. A curve may then be drawn through these points. From this graph, the series of coordinates needed in the shop to make the form tool can be readily measured. In Fig. 2 is shown an enlarged graph of this profile.

Hob Tooth Thickness at Pitch Line: The thickness of the hob tooth at the pitch line would be determined as follows:

N = number of splines;
R = pitch radius of spline shaft;
A = half thickness of spline; and
T = thickness of hob tooth at pitch line.

$$T = \frac{2\pi R}{N} - 2A$$

In the foregoing example, $N = 10$; $R = 0.75$; and $A = 0.115$. Then,

$$T = \frac{6.2832 \times 0.75}{10} - 0.23 =$$

Calculations for Hob Tooth Form for S A E 1 1/2-Inch Ten-Spline Shaft

E	3°	6°	9°	12°
D	78° 10′ 48″	75° 10′ 48″	72° 10′ 48″	69° 10′ 48″
Cos D	0.20484	0.25550	0.30603	0.35548
Sin D	0.97879	0.96681	0.95200	0.93468
R cos D	0.15363	0.19163	0.22952	0.26661
R cos $D - A$	0.03863	0.07663	0.11452	0.15161
y	0.00791	0.01958	0.03505	0.05389
X	0.03781	0.07408	0.10902	0.14171
Arc E	0.05236	0.10472	0.15708	0.20944
R arc E	0.03927	0.07854	0.11781	0.15708
x	0.00146	0.00446	0.00879	0.01537
E	15°	18°	21°	24°
D	66° 10′ 48″	63° 10′ 48″	60° 10′ 48″	57° 10′ 48″
Cos D	0.40386	0.45119	0.49728	0.54200
Sin D	0.91482	0.89243	0.86759	0.84038
R cos D	0.30290	0.33839	0.37296	0.40650
R cos $D - A$	0.18790	0.22339	0.25796	0.29150
y	0.07589	0.10079	0.12828	0.15799
X	0.17189	0.19936	0.22380	0.24497
Arc E	0.26180	0.31416	0.36652	0.41888
R arc E	0.19635	0.23562	0.27489	0.31416
x	0.02446	0.03626	0.05109	0.06919

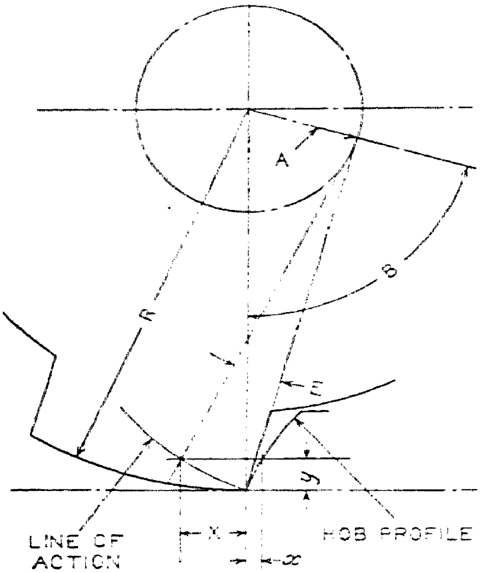
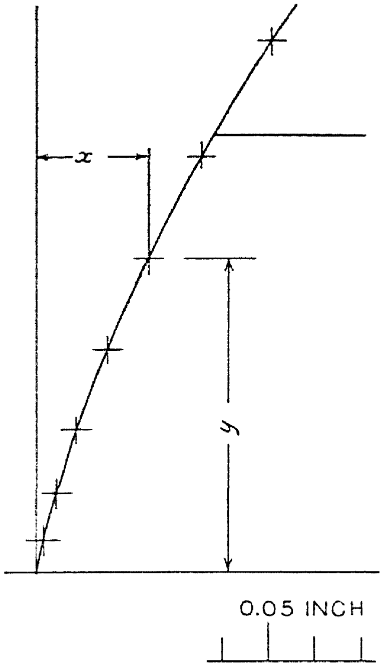


FIG. 1



SCALE
FIG. 2

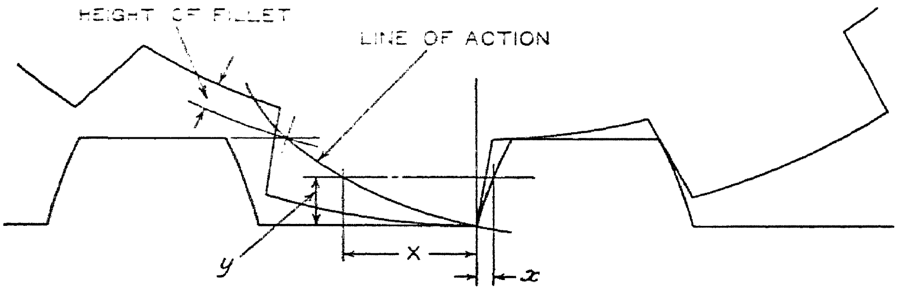


FIG. 3

Figs. 1, 2 and 3. Method of Laying Out Hob Tooth Profile for Straight-sided Splines

This hob tooth profile, line of action, and a section of the spline shaft are shown in Fig. 3. The height of the fillet at the bottom of the spline can be determined, as indicated, by measuring the distance along a radial line of the spline shaft between the intersection of the line of action and the line representing the tops of the hob teeth and the root of the spline.

Eliminating Fillet at Root of Spline: The fillet at the root may be practically eliminated by making the hob over size and cutting

away in a circular form the outside diameter at the middle, as shown in Fig. 4. The minimum amount over size in radius can be determined by measuring, along a line perpendicular to the axis of the hob, the distance between the outside of the conventional hob and the intersection of the line of action with the root circle of the spline.

Let R_r = root radius of spline;
H = lead angle of hob;
R_h = radius of form of outside of hob.

Then,

$$R_h = \frac{R_r}{\text{[illegible]}^2 H}$$

The outside of the hob blank would be turned to form. The roughing out of the thread and the cutting of the gashes, and also the relief of the sides of the hob teeth, would be done in the usual manner. The relief of the cylindrical portion of the outside of the hob would also be done in the usual way. In addition, the curved section of the outside of the hob would be relieved by a form tool, and this relief would be done without any lead, or movement in an axial direction.

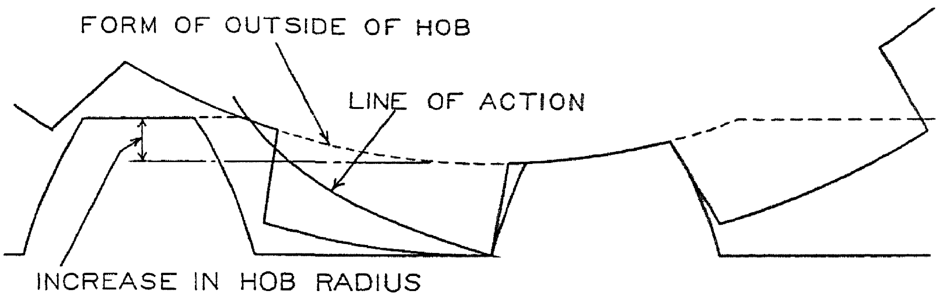


FIG. 4

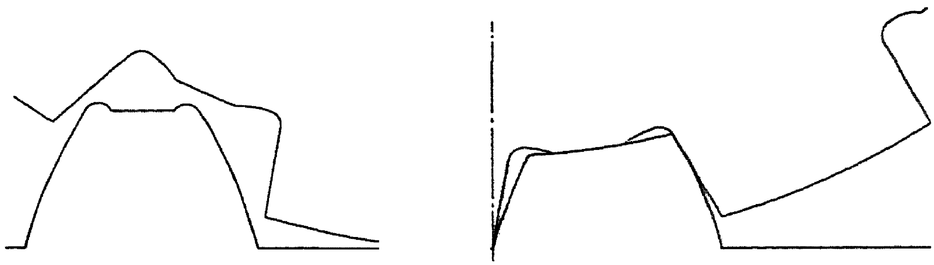


FIG. 5

Fig. 4. Modification of Hob Form to Eliminate Fillet at Root of Spline. Fig. 5. Hob Modified to provide Grinding Clearance at Root of Spline

Clearance at Root of Spline: A hob of this type could also be made to cut grinding clearance at the root of the spline, as shown in Fig. 5. In this case, the relieving tool for the sides of the hob teeth would be made to relieve the tops also. The relief of the outside of the central part of the hob would then be obtained as before.

Hobs, Taper. Hobs that are tapering on the leading end and that feed tangentially are especially adapted for cutting worm-gears of large helix angle. The use of a taper hob makes it possible to cut worm-gears more rapidly than with a fly-cutter, and also very accurately, provided the hob itself is accurate. The taper-hob method also increases the rate of production as compared with the use of straight hobs which are fed in radially. In the taper-hob method, the rotation of the hob relative to the blank, as the hob moves tangentially, is such as to advance or screw the hob slowly along its own thread. The action of the hob is the same as that of a fly cutter, and machines adapted for the fly-cutter method may also be equipped with taper hobs. The leading teeth on the hob are tapering, and they should be designed to increase progressively in width as well as in height from the small to the full-size end. The tapering or leading end performs a roughing operation, whereas the full-sized teeth take light finishing cuts, thus preserving their accuracy and insuring well formed teeth. The tangential feeding movement continues until the large end of the hob passes out of contact on the side opposite the starting point.

Hob Taps. Hob taps are, as a rule, only intended for final finishing or sizing of the threads in dies. For this reason, their construction differs from that of ordinary hand taps. They are merely used for burring a thread already cut with ordinary taps. Straight hob taps are not relieved either on the top or in the angle of the parallel portion of the thread. Two or, at most, three threads, however, are chamfered at the point of the tap, and these chamfered threads are relieved on the top of the thread the same as ordinary hand taps.

Hoepfner Process. Two processes for the electrolytic production of metals are known as "Hoepfner" processes, from the inventor. One is the Hoepfner process for the electrolytic production of copper directly from its ore. In the Hoepfner zinc process, the zinc ore is first roasted, the zinc dissolved, and deposited by electrolysis, with insoluble anodes.

Hoisting Rope. Hoisting rope is made from 6 strands of 19 wires each, and is used for elevators of all kinds, mines, conveyors, derricks, etc. The wires are smaller than those used in the 6 by 7 haulage rope and are, therefore, not as well suited to resist

abrasive action, but the rope can be more easily bent over sheaves and drums. *Special flexible hoisting rope* consists of 6 strands with 37 wires each, and is used for cranes, counterweights, dredges, and similar purposes. It possesses greater flexibility than the ordinary hoisting rope and can be bent over smaller sheaves, but is not suitable for use where it would be exposed to a great deal of external wear, because the wires are of small size and rapidly wear off. *Extra-flexible hoisting rope* is made from 8 strands of 19 wires each, and is used for practically the same purposes as special flexible hoisting rope. It has about the same flexibility as this rope but is not as strong for a corresponding diameter, because it has a larger central hemp core.

Hoisting Slings. Slings for hoisting are made of chain, wire rope, or manila rope.

Chain Slings: Chain slings are used to the greatest extent, because they are flexible and lend themselves readily to most of the hoisting operations met with in industrial work. Care must be taken, however, in the use of these slings, inasmuch as frequent strains slowly weaken the chain by crystallization, a condition which, though serious, is not readily visible. Weakness caused by surface wear or the slight opening of a single link is also likely to escape notice. Breakage of single links occurs often in cheap chains insecurely welded. Only the very best tested chain should be used.

Strength of Chains: In calculating the strength of chains, it should be observed that the strength of a link subjected to tensile stresses is not equal to twice the strength of an iron bar of the same diameter as the link stock, but is a certain amount less, owing to the bending action caused by the manner in which the load is applied to the link. The strength is also reduced somewhat by the weld. The following empirical formula is commonly used for calculating the breaking load, in pounds, of wrought-iron crane chains:

$$W = 54{,}000D^2,$$

in which W = breaking load in pounds and D = diameter of bar (in inches) from which links are made. The working load for chains should not exceed one-third the value of W, and, in many cases, it should be less. When a chain is wound around a casting and severe bending stresses are introduced, a greater factor of safety should be used.

Wire Rope Slings: Wire rope is often used for slings. Undue wear is promptly shown by broken or worn wires on the surface, which gives warning that the rope is in an unsafe condition. A wire rope sling is also stronger than a chain sling of equal size and weight. Wire rope, however, should be of the best material. By substituting the better grades of steel rope, much smaller,

lighter, and more easily handled slings can be employed. Wire rope for general service is usually composed of six strands of wires wound about a hemp core to make the rope pliable and to provide a cushion to reduce internal friction of the wires. When used in proximity to heat, however, as when handling molten metal, wire rope slings provided with a soft iron core, even if the slings are less flexible, should be used. In such service a hemp center may be destroyed and the rope deformed.

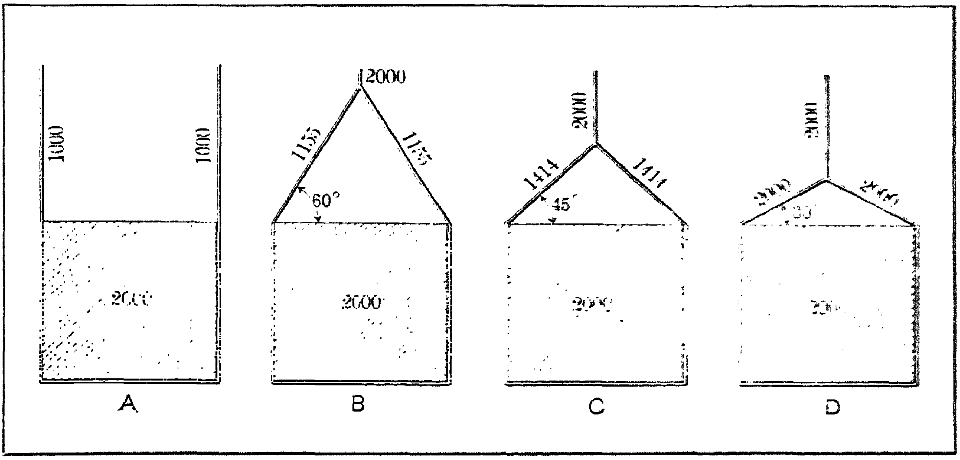
Spliced ends are more dependable than clamped ends. Load strains which stretch the rope slightly reduce its diameter to a certain extent, and the ends are likely to slip through the clamps. Splices should always be made by experts. Small plants may not be properly equipped for splicing wire rope, in which case it is desirable to have this work done at wire rope factories, where it can be done well, and at small cost. It is often advisable to wrap the splice closely with soft wire, not to increase its strength but to protect the hands of the workmen from protruding wire ends. Instead of splicing the ends, forged steel sockets with hooks, eyes, or other fittings are frequently secured to the rope by spreading the wires in the socket and pouring zinc into it, between and around the wires. Sockets should also be attached by experts to insure secure connections. Wire rope manufacturers are equipped with special facilities for doing this work economically.

Manila Rope Slings: Manila rope is much weaker than wire rope, wears easily, and cannot be utilized where it would be exposed to flame or to charring temperatures. It weakens if allowed to remain wet, and should, therefore, be promptly dried. Although the strands are easily cut if the rope is used for handling sharp-cornered loads, the frayed condition of the rope gives prompt warning of undue wear and weakness. If manila rope slings are to be employed, it is advisable to buy the best long-fibered rope obtainable. The splices must be carefully made. Manila rope should never be looped with wire rope, as the smaller wire rope will cut through the strands of the soft manila rope.

Hoisting Sling Application to Load. The method of attaching slings to the load and to the hook of the hoisting cable is of great importance; and this part of the work should be entrusted only to experienced and responsible persons. Loads may often be safely hoisted by the use of a single sling, but in other cases two or three slings may be required, the number depending not only upon the weight of the load but also upon its shape. The stresses thrown upon slings and ropes vary a great deal with conditions and are often influenced to a marked degree by circumstances which the casual observer might consider trivial and unimportant. In particular, the inclination or obliquity of the sling,

in those parts which lie between the supporting hook and the points at which the sling first touches the load, must be carefully considered, as it is a highly important feature in connection with safety.

In order to emphasize the effect that the obliquity of the sling has upon the intensity of the stress, and to avoid the necessity of repeatedly qualifying statements regarding the allowance for the stiffness of wire cables and for other circumstances, assume that the sling is perfectly flexible, and also that the load is symmetrical in shape and symmetrically supported, and that the branches of the sling (between the hook and the load) are equal in length and equally inclined. For simplicity, also assume that the total load to be supported is 2000 pounds in each case.



Views showing Variation in Sling Stresses resulting from Different Angles

Under these conditions, if the ends of the sling are exactly vertical, as at *A* (see accompanying illustration), the stress on each end will evidently be 1000 pounds. If the ends are inclined, however, as shown at *B*, *C*, and *D*, the stress upon each one will be greater than 1000 pounds in every case, and it will increase as the obliquity of the ends increases—that is to say, as they become more and more inclined toward a horizontal position. This is because the stress on each of the inclined ends must have a vertical component equal to 1000 pounds; and as there must also be a horizontal component whenever the sling stands obliquely, the total tension in each of the inclined ends must always exceed 1000 pounds.

If the sling is of such a length that its ends, between the hook and the load, are inclined to the horizontal at an angle of 60 de-

grees, as indicated at *B*, the stress on each side will be 15.5 per cent greater than it would be if the sides were vertical; that is, each side will be subject to a total stress of 1155 pounds. To find the stress on each side, multiply one-half of the load by the cosecant of the angle with the horizontal. If the sides of the sling make an angle of 45 degrees with the horizontal, as shown at *C*, the tension on each of them will $= \frac{2000}{2} \times 1.4142 = 1414$ pounds. If the angle is 30 degrees with the horizontal as shown at *D*, each side will be subject to a stress of 2000 pounds. The stress will continue to increase in a still more rapid ratio as the angle is decreased and when the sides of the sling approach the horizontal position quite closely, the stress upon them may become very great indeed. For example, if the sling were so short that its sides made an angle of only 5 degrees with the horizontal, each side would have to support a stress of 11,474 pounds.

These figures show very clearly the importance of giving careful attention to the inclination of the free ends of the sling. Men engaged in hoisting often take it for granted that the tension on a sling is everywhere the same, and if the sling be strong enough to support the load in safety when the ends are vertical, they assume that it is safe to hook it around the load in any way whatever. The sling should always be long enough to allow the ends to be at least as steep as shown at *C*, or, in other words, the ends should never make an angle of less than 45 degrees.

Hoists. The hoists used in machine shops and various classes of industrial plants, for lifting heavy parts, may be broadly classified as *hand-operated* and *power-operated* hoists. The common types of power-operated hoists are driven either by an electric motor or a pneumatic motor; with the so-called "air hoists," the load is lifted by the direct application of air pressure in a cylinder containing a piston that is attached to the lifting member of the hoist. The *differential hoist* or chain block, which was invented in 1854 by Thomas A. Weston, is based upon the principle of the Chinese windlass, an endless chain being substituted for the windlass rope and iron sheaves for the wooden drum. The chain hoist commonly known as the "screw" or "screw-geared" type, is so named because the power is transmitted from the hand chain to the load chain through a worm or screw which meshes with a worm-wheel. The spur-geared type of chain hoist is now used extensively and, if properly designed and built, is efficient.

Many *electric hoists* are equipped with motor-driven trolleys, some of which are controlled from the floor by pendant cords, while others have an operator's cage. When an electric hoist is not attached to a trolley, it is usually provided with a hook so

that it can readily be suspended from a crane, or wherever the hoist is needed. The hoist is controlled by pendant cords or chains from the floor, connected with a variable-speed controller which operates in conjunction with the brake.

The air-motor or pneumatic, geared type of hoist is equipped with some form of air motor which drives the lifting drum through suitable reduction gearing.

Air Hoists: There are three general classes of *air hoists* of the cylinder type. With the *single-acting type*, compressed air is admitted to the lower or stuffing-box side of the piston only, and, when lowering the hoist, this air is exhausted. The *air-balanced type* of hoist is so arranged that there is full air pressure on the stuffing-box side of the piston at all times. The load is hoisted by exhausting air from the space above the piston, and is lowered by admitting air above the piston; the unbalanced area due to the space occupied by the piston-rod aids in forcing the piston downward. The advantage of this arrangement is accuracy of control. The *double-acting type* differs from the balanced type in that air may be admitted and exhausted from either side of the piston, so that the latter may be moved in either direction with equal power. Thus, with a balanced hoist, there is a constant pressure on one side of the piston and a variable pressure on the other, whereas, with a double-acting type, the pressure on either side of the piston may be varied in accordance with the amount of the load and the direction in which the force must be applied. For this reason, hoists of the double-acting type are used whenever either a pushing or pulling effect may be required.

Hold-Back Dog. See Dogs or Drivers.

Hollow-Blast Grate. This is a furnace grate designed especially for the burning of wood refuse, such as sawdust, bark, and chips, which cannot be easily burned on an ordinary form of grate. The grate consists of a series of hollow bars connected with a blast fan, air being admitted to the fire through openings in the upper surfaces of the bars.

Hollow-Mills. Hollow-mills are used for reducing the diameter of round stock and are frequently employed in connection with spring screw threading dies, taking a cut preceding the die. Hollow-mills are usually made adjustable, the adjustment being obtained with a clamp collar the same as in spring screw threading dies.

Holly Method. This is a method of operation of Bessemer converter plants in which the burned-out converter is removed by a crane or car and one that has been lined and dried in a separate shop is substituted for it.

Homo-Polar Machine. See Acyclic Machines.

Honing Process. The honing process is a method of imparting a mirror-like finish to important bearing surfaces by means of hones or abrasive stones which ordinarily have a combined rotary and longitudinal motion. The honing process is used for finishing the bores of automobile and aircraft engine cylinders and is also applied to various other high-class bearing surfaces. Such a process is particularly applicable when bearing durability and operating efficiency are important factors. If a bearing surface has an ordinary finish, an initial wear occurs during the early stages of the machine's life. This is due to the fact that an ordinary surface, as seen through the microscope, consists of minute ridges having very small areas at the top and subject to rapid wear. The purpose of the honing process is to eliminate these extremely minute ridges and provide more nearly perfect bearing surfaces. The difference between an ordinary surface and one finished by honing may be slight in so far as appearance is concerned. There is, however, a decided difference in the matter of quality, and on many classes of machines these finely finished surfaces have important practical advantages.

The honing process involves the use of an expanding tool provided with relatively long and narrow abrasive stones. By simultaneously reciprocating and rotating this honing tool in a bored and reamed cylinder, great accuracy and a mirror-like finish can be obtained. Honing enables cylinder bores to be finished to within 0.0005 inch of the specified diameter, as well as straight and round within the same tolerance. The general practice in automobile plants is to remove approximately 0.002 to 0.003 inch of stock on the diameter of cylinder bores by rough-honing. Then a secondary honing operation, in a very few cycles, removes a minute amount of stock and produces the mirror-like smoothness and high accuracy. While most honing operations are internal, the process is applicable to external surfaces. See also Superfinishing Process.

Hook Bolt. See Bolts.

Hooke's Coupling. Hooke's coupling, generally known as the "universal joint," is employed for connecting two shafts, the axes of which are not in line with each other, but which merely intersect at one point. Sometimes two shafts, the axes of which are in different planes, and, hence, do not intersect at any point, are connected with an intermediate shaft which is joined to each of the two shafts by universal joints. Many designs of flexible shafts are simply a combination of universal joints.

"Hooking Up" a Locomotive. When starting a train, the engineer places the reversing lever all the way forward (if mov-

ing in that direction); the valve then receives the full motion from the eccentric or "eccentric crank" which operates it, the cut-off occurs at the latest point, and the power of the locomotive is maximum. When the train gets under way, the reverse lever is "hooked up" toward the center, thus shortening the travel of the valve, which causes an earlier cut-off; consequently, there is greater expansion of the steam and less steam consumption. The power is reduced, but, since the train is under way, less power is required.

Hook-Tooth Sprocket. This is a sprocket for link-belting, used to transmit power from or to a chain running in a straight or nearly straight line. It is sometimes employed as an idler for returning a horizontal slack chain, if the drive is intermittent and there is a tendency for the chain to jump off an ordinary sprocket.

Horning and Wiring Press. Presses of this general type are used in the manufacture of tin pails, coffee pots, baking pans, and similar articles. For many operations on such parts, the work must be inserted over a projecting arm or horn which may be either cylindrical, tapering, square, or of a special shape. While supported by this horn or die, the operations are performed by the punch.

Horsepower. In mechanics, *work* is the product of force by distance, and is expressed by a combination of units of weight (force) and distance, as inch-pounds, foot-pounds, foot-tons, etc. *Power*, in mechanics, is the product of force by distance divided by time, or the performance of a given amount of work in a given time, and is expressed as inch-pounds per minute, foot-pounds per minute or second, etc. The term *power* is frequently used by writers on mechanics to designate a *force*. In connection with the so-called "mechanical powers"—the lever, wheel and axle, wedge, screw, etc.—it is usual to speak of the applied force as the power; this is, however, not strictly correct, as power should always, in mechanics, be used in accordance with the definition given above. *Horsepower* (abbreviated H.P.) is the unit of power adopted for engineering work. One horsepower is equal to 33,000 foot-pounds per minute, or 550 foot-pounds per second.

The *metric horsepower*, used in countries where the metric system is employed, is equal to 75 kilogrammeters per second, or 542.5 foot-pounds per second, or 32,550 foot-pounds per minute. The *kilowatt*, used in electrical work, equals 1.34 horsepower; or one horsepower equals 0.746 kilowatt. The horsepower unit was introduced by James Watt, the great improver of the steam engine, for the purpose of designating the power developed by his engine. It is said that he had ascertained by experiments that

an average cart horse could develop 22,000 foot-pounds of work per minute, and being anxious to give good value to the purchasers of his engines he added 50 per cent to this amount, thus obtaining (22,000 + 11,000) the 33,000 foot-pounds per minute unit by which the power of steam and other engines has ever since been estimated.

Electrical Equivalent: The British Association for the Advancement of Science adopted, as early as 1873, 746 watts as the equivalent of the British and American horsepower, and 736 watts as the equivalent of the metric or Continental horsepower. In a circular issued by the United States Bureau of Standards, it is stated that in all future publications of this bureau the former value, 746 watts, or 0.746 kilowatt, will be used as the exact equivalent of the English and American horsepower. For scientific work, it is quite important to have the horsepower thus standardized by being expressed in the so-called "absolute system of measurement," because the common definition of 550 foot-pounds per second is scientifically correct only at a certain latitude and altitude, on account of the fact that the pound-weight, as a unit of force, varies in value as g, the acceleration of gravity, varies. The horsepower when expressed as 746 watts is equal to 550 foot-pounds per second at 50 degrees latitude and at sea level. See Steam Engine Horsepower Rating.

Horsepower, Belting. See Belt Power-transmitting Capacity.

Horsepower, Boiler. See Boiler Capacity Rating.

Horsepower Formula for Automobile Engines. Brake horsepower rating is usually based upon the maximum speed of 3400 to 3600 R.P.M., although some manufacturers' power ratings are based upon speeds up to 4000 R.P.M. The horsepower of a motor may be determined approximately by the following formula in which D = cylinder diameter, in inches; S = length of stroke, in inches; and N = number of cylinders.

$$\text{Horsepower} = 0.32\, D^2 SN$$

The constant 0.32 may range from 0.3 to 0.37 for the power ratings of different manufacturers, but 0.32 is a fair average.

Horsepower-hour. A unit of work or energy equivalent to one horsepower acting one hour. 1 horsepower-hour = 0.746 kilowatt-hour = 1,980,000 foot-pounds = 2545 B.T.U. (British thermal units) = 2.64 pounds of water evaporated at 212° F. = 17 pounds of water raised from 62° to 212° F.

Horsepower, Metric. See Metric Horsepower.

Hose Couplings. The American Standard for Hose Coupling Screw Threads includes the following classes and nominal sizes:

Garden and Similar Hose: The nominal sizes are $\frac{1}{2}$, $\frac{5}{8}$, and $\frac{3}{4}$ inch, and the number of threads per inch is $11\frac{1}{2}$ in all cases.

Chemical, Engine, and Booster Hose: The nominal sizes are $\frac{3}{4}$ and 1 inch, with 8 threads per inch for both sizes.

Fire Protection Hose: There is a single size of $1\frac{1}{2}$ inches in this standard, with 9 threads per inch.

Steam, Water, Air, Oil, and All Other Hose Connections: There are six nominal sizes as follows: $\frac{1}{2}$- and $\frac{3}{4}$-inch sizes, with 14 threads per inch; 1-, $1\frac{1}{4}$-, $1\frac{1}{2}$-, and 2-inch sizes, all with $11\frac{1}{2}$ threads per inch.

These hose couplings all have the American Standard form of thread.

Hose Couplings, Fire. The National (American) Standard Fire-hose Coupling Screw Thread applies to fire hose couplings, hydrant outlets, stand-pipe connections, and other fittings on fire lines having nominal inside diameters of $2\frac{1}{2}$, 3, $3\frac{1}{2}$, and $4\frac{1}{2}$ inches. The screw thread for the $2\frac{1}{2}$-inch inside diameter has $7\frac{1}{2}$ threads per inch and a pitch diameter of 2.997 min. and 3.013 max.; the 3-inch size has 6 threads per inch and a pitch diameter of 3.5306 min. and 3.5486 max.; the $3\frac{1}{2}$-inch size has 6 threads per inch and a pitch diameter of 4.1556 min. and 4.1736 max.; the $4\frac{1}{2}$-inch size has 4 threads per inch and a pitch diameter of 5.6235 min. and 5.6485 max. The thread form in all cases is the American Standard (formerly known as U. S. Standard).

This fire-hose coupling thread standard has been approved and adopted by the American Water Works Association, Brass Hose Fittings Manufacturer's Association, Bureau of Standards—U. S. Department of Commerce, International Association of Fire Engineers, National Board of Fire Underwriters, National Fire Protection Association, National Screw Thread Commission, Railway Fire Protection Association, The American Society of Mechanical Engineers, The National Firemen's Association of the U. S., and other organizations.

Hot Bearings. Investigation has shown that the main reasons for excessive heating of babbitted bearings are: 1. Shrinkage or contraction of the babbitt. 2. Shrinkage strains set up in the babbitt metal liner by the unequal distribution of the babbitt metal over the shell. 3. A lack of contact between the babbitt metal liner and the cast-iron or cast-steel shell. 4. The lubricant becomes partially deflected into the wrong place.

Hot-Milling. Milling off a small amount of metal from the cutting edges of forged tools while they are still at the forging heat is known as "hot-milling" and is used in the production of rock drill bits. On ordinary forged rock drill bits, the surfaces

are scaled and pitted, with discolored patches which indicate that changes have taken place in the composition of the surface material. Hot-milling removes this coating and exposes the unaffected material, so that the bit can be properly hardened. The hot-milling operation also brings the bits to the correct shape and size. An interesting point is that a lower temperature can be used when hardening a hot-milled bit, as the quenching medium does not have to penetrate the scale and skin left by the forging operation.

Hot-Pressed Brass Parts. Hot-pressed parts are formed in dies by means of a press which exerts enough pressure on a heated slug of forgeable brass to cause the metal to flow and fill the die cavity. The term "hot pressing" is generally applied when some type of power press or hydraulic press is used, whereas, if brass parts are formed in dies under a drop-hammer or steam hammer, the process is known ordinarily as brass forgings. Both methods produce die-formed brass parts to replace small brass castings or machined parts such as are produced on screw machines or turret lathes.

The brass slugs, prior to hot-pressing, are heated in a gas, oil or electric furnace to a temperature of about 1450 degrees F.; then the heated slug is inserted in the die and the part is pressed. The pressed pieces are usually subjected to a pickling process to produce a glossy bright surface; they resemble die castings and the surfaces, in many cases, are smooth enough to permit polishing without previous grinding. Hot-pressed parts can be held to limits of plus or minus 0.002 inch on a diameter not exceeding 1 inch. On a diameter of from 1 to 2 inches, the sizes will vary by plus or minus 0.004 inch. Smaller sections than 1 inch can be held closer. Shoulders can be held to plus or minus 0.002 inch.

Alloys for Hot Pressing: Brass containing 60 per cent copper and 40 per cent zinc is quite forgeable and suitable for the manufacture of hot-pressed parts. The extruded brass shapes now on the market are also suitable for hot pressing; moreover, if the cross-section selected conforms approximately to the shape of the die, the forging of the slugs is facilitated. The slugs, however, should not conform too closely to the shape of the finished forging because the metal must flow under pressure to get the best results. Other metals which can be hot pressed include aluminum, dur-aluminum, monel metal, and similar compositions of a forgeable nature.

Presses Used: The percussion press, which has a screw-operated slide and a friction drive, is particularly adapted to hot-pressing of brass and steel parts. The friction drive gradually accelerates the flywheel (located at the upper end of the screw)

and the cumulative quality of the blow delivered causes the heated slug to flow and completely fill the die cavity. The part is finished with one stroke of the press and the slide returns automatically to its upper position.

Both single- and double-acting crank presses, and hydraulic presses, have also been used for hot pressing.

Dies Used for Hot Pressing: Hot-pressed brass parts may be produced in three types of dies. *Open dies,* similar to those used in drop forging, may be employed, but the forged parts have a flash or fin which must be removed by trimming. In using *extrusion dies,* the material is confined and forced by the punch to pass through a smaller opening in the bottom, assuming that the forging has a large head and a small stem. In forging a shell or bushing, the metal can be forced to rise up around the punch. *Confined dies* represent the third type. The descending punch closes the die and the metal is compelled to flow in all directions, thus filling the die cavity. It may be necessary to make confined dies in sections in order to remove the finished piece. For some work, there is an advantage in lubricating the dies. See Brass Forging.

Hot-Pressed Steel Parts. A hot-pressing process similar in principle to that employed in hot-pressing brass parts may be applied to a variety of small steel parts. In hot-pressing steel, the slugs of steel are heated to about 1800 degrees F. and are then pressed to the desired shape in tungsten steel dies having cavities corresponding to the form required. The dies have tungsten steel inserts which are backed up by machine steel.

Hot Top. In the manufacture of steel, the molten metal from the crucible, converter, or electric furnace is poured into ingot molds. The impurities which float on the top of the molten metal are carried to the top of the mold, which is fashioned with a temporary "hot top" made of some refractory material. By this means the top of the ingot containing the impurities can be sheared off after the ingot is cold.

Hot-Well. "Hot-well" is the name given the reservoir that receives the cooling water and the condensed steam from a jet type of condenser, or the condensed steam from a surface condenser. The hot-well need not be closed tight, as there is no pressure in it, and it simply serves as a cistern for holding the warm water discharged from the condenser. The feed pump for the boiler of a condensing engine draws water from the hot-well. In land practice, the hot-well is usually arranged with an overflow so that the excess of water not needed by the boiler may escape.

Hot-Wire Meter. This is an instrument for measuring electric current in which the current passes through a straight wire,

the amperage being measured by the expansion of the wire caused by the heating effect of the current. The expansion is transmitted by a lever to an indicating needle. The thermocouple type of meter is now largely used in place of the hot-wire meter because of lower power loss and greater sensitivity. See Ammeter.

"Hot-Work" Steels. The term "hot work" is commonly applied to steels adapted for forging dies or other operations on heated metal. In the selection of die steels for use in modern forging equipment, special consideration must be given to the resistance of the steel to heat, abrasion, and pressure. It is not possible to select a hot-work steel that will possess maximum ability to meet all of these service conditions. In one case, it will be necessary to select a steel having maximum resistance to heat and to abrasion. In another case, the ability to withstand pressure, shock, and fatigue will be the governing factor.

Hot-work steels may be classified broadly as the tungsten (or molybdenum) type and the chromium type. The accepted usage of the term "hot-work steels," covers all steels used in manufacturing dies, shears, punches, etc., for use in forging machines, presses, hot trimmers, etc. The hot-working of metal is also performed extensively under forging hammers equipped with die-blocks made of chromium-nickel-molybdenum steel.

Tungsten steels offer excellent resistance to heat and abrasion. Molybdenum possesses heat-resisting properties similar to tungsten, and is sometimes used in analyses in place of tungsten in quantities equal to about one-half the tungsten content. Tungsten is an expensive element, but on jobs where dies operate at high temperatures, tungsten steels prove the most economical. Chromium is next to tungsten and molybdenum in heat-resisting qualities. Chromium steels are used largely in automatic hot-working machines where resistance to repeated impact and to heat is important.

Hoyle's Metal. Hoyle's metal is a bearing metal of the lead-tin-antimony alloy class, composed of 42 per cent of lead, 46 per cent of tin, and 12 per cent of antimony.

Hub Method of Die-Sinking. The "hub" or "hob" method has long been employed for making dies such as are used in producing coins, medals, and various products of the silversmithing and jewelry trades. A hub is used, which is in the form of a punch and has a shape corresponding to the impression required in the die. In other words, the hub, at its formed end, is a duplicate in hardened tool steel, of the part to be molded in the die. While this hub must be made accurately and be given a fine finish, it is, of course, much easier to produce than would be a cavity or impression of corresponding shape. Furthermore, after the hub

is made, it can be used to advantage in reproducing duplicate impressions in a number of different dies. The hub is hardened so that it will withstand the extremely high pressures employed in connection with the production of dies by this method. In a general way, the method consists in forcing the hub into the unheated die blank by means of hydraulic power so that the shape of the hub is reproduced in the die impression.

Humidity Measurement. See Hygrometer.

Humid Process. In assaying, the humid process, also known as the "wet process," is a method of testing alloys, especially for ascertaining the quantity of silver or gold contained. The process consists in dissolving the metals by acids and afterwards precipitating them.

Hunting. Hunting, in electrical engineering, is a periodic increase or decrease in the speed of synchronous machinery operating in parallel, such as generators or motors. It may be due to several causes, such as irregular action of the prime movers, or a variation of the supply voltage, as caused, for example, by the drop due to a relatively high resistance and reactance in the supply line. A short circuiting or amortisseur winding in the pole faces is one means of damping out hunting action.

Hunting Tooth. When one of two meshing gears is provided with one more tooth than it would have if the numbers of teeth in the two gears were in an even ratio to each other, this extra tooth is commonly known as a "hunting tooth." For example, if a driven shaft is required to revolve three times as fast as the driving shaft, this result could be obtained by using driving and driven gears having 72 and 24 teeth, respectively. Instead of using this exact ratio, many millwrights, when installing cast gears, would use a driving gear having 73 teeth instead of 72, and a driven gear of 24 teeth. These numbers are very close to the desired ratio, but, as they do not have a common divisor, each tooth of one gear will mesh with all of the mating teeth one after the other, instead of meshing with the same teeth continually. The theory is that when the teeth mesh progressively in this manner, thus distributing the wear, all of the teeth will eventually be worn to some indefinite, but comparatively true, shape. To illustrate the action, any two teeth which happen to meet during the first revolution will be separated by one tooth space at the completion of the second revolution, by two tooth spaces at the end of the third revolution, and so on; consequently, one tooth may be said to "hunt" the other, and hence the name "hunting tooth."

Hydracid. This is an acid which does not contain oxygen, but in which hydrogen unites directly with the principal element.

Hydraulic Accumulator. A hydraulic accumulator is used for the storing of energy to be expended intermittently for power purposes, as in hydraulic elevators, riveters, and other hydraulic machinery. One type consists principally of a vertical cylinder fitted with a plunger to the upper end of which are secured the weights necessary to produce the required pressure. Water is forced into the cylinder by a force pump. This raises the plunger, the weight of which, reacting upon the water, will transmit the pressure to the machinery operated by it. The force pumps which supply the cylinder will, by continuous running, accumulate in the cylinder, during the periods when this is inactive, an amount of energy equal to that expended during the intermittent periods of activity. The type of accumulator in which the plunger is weighted down is known as the *direct* form. Another type, known as the *inverted* type, operates on the same principle, but the cylinder fits over the plunger from above and supports the weights. A special form of accumulator, known as a *hydropneumatic* type, is so arranged that the water within the cylinder compresses air which reacts upon it, thus serving as a substitute for the weights used in the ordinary type of accumulators. Hydropneumatic accumulators are used especially in connection with hydraulic elevators and presses.

Hydraulic Jacks. Jacks of this type are especially adapted for lifting very heavy loads. There are many different designs and sizes that operate on practically the same principle. One of the most common forms of hydraulic jack is the vertical, inside pumping type. The head and interior of the ram form a reservoir from which the liquid is pumped beneath the ram for raising the jack, and to which the liquid is returned in lowering. When the liquid enters the pump from the reservoir, it is forced by the downward stroke of the piston through a lower check-valve into the cylinder and beneath the ram, which is forced upward because the pump is of small size, and owing to the leverage of the operating handle it is possible to exert considerable pumping pressure. The operating lever slips into a socket at the side of the head. This socket is mounted on a shaft which carries a short arm or lever inside of the head to which the pump piston-rod is attached. The Dudgeon *universal jack* has double pumps so that, if the load is light or if the ram must be extended some distance before the heavy load is encountered, the two pumps can be used together until the strain becomes excessive, when one pump is thrown out by a turn of the handle.

Hydraulic Presses. A hydraulic or hydrostatic press, is a machine by the use of which some forcing or pressing operation is performed by means of power transmitted through confined fluid under pressure. The hydraulic press was invented by Joseph

Bramah, an Englishman, who, in conjunction with Maudslay, laid the foundation for the development of modern metal-cutting tools. The hydraulic press, as built by Bramah, was equipped with a stuffing-box and gland for packing the ram. This arrangement, however, retarded the return stroke and caused considerable trouble until Maudslay substituted the self-tightening cup-leather packing for the stuffing-box.

That fluids, when confined and subjected to pressure, follow a definite law, was first discovered in 1653 by a French scientist. Blaise Pascal, who wrote of the results of his hydrostatic investigations in a treatise on the equilibrium of fluids. By the application of Pascal's law, the development of a tremendous force exerted through a short distance becomes possible by the exertion of very small force through a proportionally longer distance. Advantage is taken of this principle in commercial hydraulic press and pump installations.

The press is frequently separate from the pump and may be located at considerable distance from it; the pump may be of any size and type suitable for delivering the necessary volume of fluid at the required pressure per square inch; pipe lines and valves may connect the pump and press; and accumulators or other machines or apparatus may also be connected to the system: but notwithstanding all these, when hydraulic communication is open from the pump plunger to the press cylinder, Pascal's law governs, theoretically, the relations existing between the press ram and the pump plunger. Practically slight allowances may be required to compensate for losses due to friction of the water in the pipes, friction of packings, leakage, and other minor losses.

The use of hydraulic presses is confined to no particular industry, nor to any particular class of service. Almost any pressure application or any combination of pressure applications may be produced in a suitable hydraulic press. Practical conditions have, however, limited the use of the hydraulic press mainly to machines in which great pressure is a prime requisite, leaving the field of light pressure requirements to be covered largely by mechanical power presses.

Hydraulic Ram. The hydraulic ram is used to raise water from a point below the source of supply to a point which may be considerably higher than the level of the spring, reservoir or part of a stream from which the water flows to the ram. The only power required to operate a hydraulic ram is that obtained from the momentum of a moving column of water. The ram is so constructed that the water is allowed to flow intermittently, and each time its movement is suddenly stopped the kinetic energy is changed to pressure and utilized to force part of the water through a discharge valve and into an air chamber where air is

compressed, and aids in forcing a relatively small quantity of the water out through the discharge pipe. When the ram is in operation, the water flows downward through the drive pipe and through the open waste valve *B* (see illustration) until the required velocity is obtained, when valve *B* is automatically closed. During its flow, the water has developed a certain amount of energy or momentum which, when the flow is suddenly stopped, causes the water to overcome the pressure against the top of the discharge valve *S* which opens and allows a portion of the water to enter the air chamber. Immediately, a rebound occurs and for a short interval water flows out through the discharge pipe. As soon as the movement of water in the drive pipe ceases, valve *B* is opened by the action of weight *H* acting through a cam surface at *G* against which lever *E* bears. The opening of this valve causes the water in the drive pipe to again flow rapidly downward and the cycle is repeated.

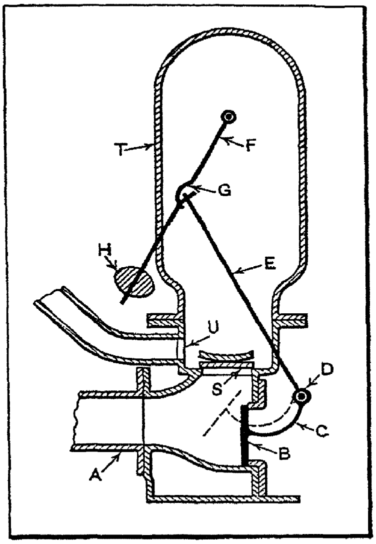


Diagram of Hydraulic Ram

Drive Pipe: The length of the drive pipe may vary from three to four times the height of the head to eight or ten times the height. According to one rule, if the head or vertical distance from the ram to the level of the source of supply is from 6 to 10 feet, the drive pipe should not be less than six times the height of the fall. If the head is less than 6 feet, the length of the drive pipe should equal from eight to ten times the head. For instance, if there is a head of 5 feet, the drive pipe should be from 40 to 50 feet long, according to this rule. A fall of 2 feet is usually considered about the minimum at which hydraulic rams will operate satisfactorily. The drive pipe should be as straight as possible and the bend near the ram should be a long gradual curve.

Discharge Pipe: The discharge pipe may vary in length from a few feet to hundreds of feet. Its diameter should vary from one-third to one-half the diameter of the drive pipe. The straighter the pipe line, the better the performance of the ram.

Quantity of Water Delivered: The amount of water that a hydraulic ram will deliver is affected by the head of water or height of the fall, the quantity available, the height to which the water is elevated, and the friction in the pipes. In general, it is esti-

mated that approximately one-seventh of the volume of water falling into the ram can be raised to an elevation five times the height of the fall, or one-fourteenth of the volume can be raised about ten times the height of the fall, and so on in like proportion according as the fall or height is increased or diminished.

Hydraulic Shears. Hydraulic shears which are used in connection with hydraulic intensifiers for giving the required pressure are designed and used for various purposes. Such shears are especially adapted for cutting off billets and blooms in rolling mills, and they are also used for shearing structural shapes.

Hydraulic Transmissions. Hydraulic transmissions are used in preference to mechanical transmissions on certain types of machines, either to drive the main working member or to provide a feeding movement for a tool or machine table. Hydraulic transmissions are now applied to many different types of machines and other mechanical devices, including various classes of presses; testing machines; mechanical stokers; cranes and hoists; ships' windlasses and steering apparatus; to certain types of machine tools, etc. In machine tool design the hydraulic transmission is utilized in preference to a mechanical transmission on certain types of machines partly with the idea of obtaining smoother action and greater flexibility of control. Hydraulic transmissions, for example, have been applied to broaching machines; to grinding machines to provide the traversing movement; to drilling machines, milling machines and some turning machines for supplying the feeding movements.

These systems, consisting of self-contained pumping and valve units, are now available for use on practically all types of machine tools. Although they are commonly called hydraulic or "fluid power" systems, no water is employed, the operating fluid being oil, which not only provides means for the hydraulic transmission of power, but also serves to lubricate the moving parts. The use of oil for transmitting power or movement to machine tables, slides, feeds, etc., has several advantages. The incompressibility of oil prevents the generation of heat and loss of energy from this source. The chemical stability of oil, its noncorrosive nature, and its lubricating properties are important advantages.

Hydraulic transmissions are designed for driven members having either a constant or variable straight-line reciprocating movement or a constant or variable rotary motion. In the case of straght-line movements, the hydraulic pressure is applied to a plunger or piston within a cylinder, whereas, for rotary motion, a hydraulic or fluid power motor is used in conjunction with the pump. In both types of transmissions, the equipment must be

designed to meet various operating requirements, as, for example, in regard to speed variations and method of controlling the speed changes or other movements; hence, both the pumps and motors are made in different types as well as in a large range of sizes.

Variable Displacement Pumps: With this type of pump, the stroke may be adjusted to obtain any volume from zero to maximum. Different types of hand and automatic power controls are employed, depending upon the type of machine and its operating requirements. Variable displacement pumps, in conjunction with cylinders and control valves, are applied to such machines as grinding, shaping, planing, honing and broaching machines; to presses, etc. Pumps of this type may be used in combination with fluid power motors when a variable rotary speed is required.

Constant Displacement Pumps: This type of pump has a fixed stroke so that the volume of oil delivered varies with the pump size and driving shaft speeds. Where variable speed is not essential or for applications requiring the repetition of a cycle, the constant displacement pumps are preferable. They are used for broaching and assembling presses, riveting machines, and for many other applications. These pumps may be used in conjunction with one or more fluid power motors.

Pumps of Duplex Type: The variable and constant displacement duplex pump is applicable when a variable-speed and high working pressure is required in conjunction with high-speed rapid traverse at low pressure. These pumps may be applied to transmissions on presses of different kinds, bending machines, riveting machines, etc.

Fluid Power Motors of Constant Displacement Type: This is a constant torque type of motor, the maximum torque being available at all speeds. When a constant displacement motor is used with a variable displacement pump to obtain a variable-speed and constant-torque transmission, the maximum horsepower transmitted is directly proportional to the motor speed. The use of these motors in conjunction with suitable pumps covers a wide range of applications. In many cases, two or more fluid motors may be applied to different parts of a machine, or they may be located on different floors, with the pump placed at whatever point is convenient in regard to the source of power. The fluid power is transmitted through pipe lines from the pump, thus greatly simplifying it as compared with a mechanical transmission.

Fluid Power Motors of Variable Displacement Type: These motors provide constant power with variable torque, the maximum power being available over a limited range of speeds. The torque decreases and the speed increases as the motor stroke is reduced. These motors, like the constant displacement type, may be applied to different parts of a machine or be installed on

different floors. They are applicable also to a large variety of industrial drives.

Advantages of Hydraulic Transmissions: Transmissions of the hydraulic type may be used in preference to mechanical transmissions because of one or more of the following advantages, depending upon the type of machine: (1) Greater flexibility of control; (2) quick reversal of motion with practically no shock; (3) "slip" which compensates for overloads or unexpected obstructions; (4) practicability of locating transmission members with reference either to power application or the design of other parts; (5) use of relief or control valves to safeguard against overloading.

Hydraulic Vacuum Pump. This is an air pump which removes the non-condensible vapors from a condenser by hurling jets of water, approximately rectangular in cross-section, at a high velocity from a revolving wheel. The water jets rush through the discharge cone and diffuser in the form of a helix enclosing the vapors, which enter around the revolving wheel, between the jets or pistons of water. The hurling water is delivered under pressure by a centrifugal pump.

Hydrocarbon. Hydrocarbon is a general name for a number of chemical combinations of carbon and hydrogen, such as marsh gas, tar, pitch, naphtha, etc.

Hydrochloric Acid. Hydrochloric acid, also known as muriatic acid, is an aqueous solution of hydrogen chloride (chemical formula, HCl). In the mechanical industries it is used either alone, or mixed with other acids as an etching fluid. It is colorless when pure, but the commercial acid has a yellow tint, due to impurities. Concentrated acid contains 32 per cent of hydrochloride and has a specific gravity of 1.16. Dilute acid, containing about 18 per cent of hydrochloride, has a specific gravity of 1.09. Hydrochloric acid gives off poisonous fumes if left open in the air, the fumes being chlorine gas. An antidote for chlorine gas poisoning consists of powdered chalk or soap dissolved in water.

Hydrofluoric Acid. Hydrofluoric acid is an aqueous solution of anhydrous hydrogen fluoride (chemical formula, HF). The acid dissolves glass, and can, therefore, be used as an etching fluid for glass, a purpose for which it is commonly employed. It also attacks most metals, and can be used as an etching fluid for metal objects as well. The acid is a colorless fuming liquid, having a specific gravity of 1.25, when in a saturated solution. Gases given off by hydrofluoric acid are poisonous, and the acid also is injurious, if applied to the skin. As it dissolves glass, it is generally kept in lead-lined vessels. Hydrofluoric acid is also used

for a quick pickle for hot castings. It is also used in conjunction with soda, as a water softening compound for boiler feed water. The acid attacks practically all materials that could be used as containers for it except lead, platinum, gutta-percha, and some clays. When etching glass by means of this acid, the glass is first coated by a light coating of melted paraffin or an etching varnish made from asphaltum and beeswax. In making this varnish the wax is first melted and the asphaltum stirred into it, after which the mixture is boiled until, upon cooling, it will harden readily.

Hydrogen. Hydrogen is a gaseous chemical element, the symbol of which is H, and the atomic weight, 1.008. The specific gravity, as compared with air, is 0.0694. Its specific heat equals 3.40. It becomes fluid at a temperature of —252 degrees C. (—421 degrees F.), and solidifies at a temperature of —258 degrees C. (—432 degrees F.). Hydrogen is one of the chemical constituents of water, oxygen being the other constituent. Hydrogen burns with a pale blue non-luminous flame at high heat, the oxyhydrogen flame being used in autogenous welding and in flame-cutting processes. With air or oxygen, hydrogen forms a highly explosive mixture, especially in the proportion of two volumes of hydrogen to one volume of oxygen. It is, therefore, important to take care that free hydrogen does not mix mechanically with air or with free oxygen. Hydrogen is produced commercially as a by-product in the production of oxygen by the electrolytic method.

Hydrogen Brazing. See Brazing, Hydrogen Process.

Hydroline. Hydroline or "hydrolene," as it is sometimes called, is a trade name given to the petroleum pitch which remains after the cracking of petroleum oil. This pitch is usually graded as soft, medium, and hard, according to the melting point which ranges from 50 degrees centigrade to 150 degrees centigrade and higher.

Hydro-Metallurgical Process. This process, also known as *wet process*, is a method for obtaining a metal from its ore by dissolving the ore in a solution from which the metal can be precipitated. This method was developed for copper ores of low grade containing only from ¼ to 1 per cent of copper. The copper obtained by the precipitation is known as *cement copper*.

Hydrometer. The hydrometer may be defined as an instrument for determining the density or specific gravity of a liquid. Special hydrometers are also used for other purposes. Classified in the broadest sense, there are two types of hydrometers; namely, hydrometers proper and hydrometers that are combined with thermometers, generally known as "thermohydrometers."

Hydrometers proper may be divided into four specific classes: (1) Density hydrometers, which indicate the density of a liquid on a given scale. (2) Specific-gravity hydrometers, which indicate the specific gravity or relative density of a liquid as compared with water. (3) Per cent hydrometers, which indicate the percentage of a substance in a mixture or solution with water. (4) Arbitrary-scale hydrometers, which indicate the concentration or strength of a liquid on an arbitrarily defined scale. This latter class includes the well-known Baume type of hydrometer. The hydrometer consists of a glass tube having a weight at one end, so that it will float in a vertical position in the liquid the density of which is to be measured. The glass tube is provided with graduations on which the density is read off. When reading a hydrometer, the liquid is placed in a glass jar or cylinder, and the hydrometer carefully immersed in it to a point slightly below that to which it would sink by itself, and is then allowed to float freely. The reading should not be taken until the liquid and the hydrometer are fully at rest. The reading should be taken with the eye placed exactly in the plane of the surface of the liquid.

Hydro-Pneumatic Accumulator. This is a hydraulic accumulator in which the water within the cylinder compresses air which reacts upon it, thus serving as a substitute for the weights used in the ordinary type of accumulator. This type has been applied in connection with hydraulic elevators and presses.

Hydrostatic Joint. This is a type of joint used in large water mains, in which sheet lead is forced tightly into the bell of a pipe by means of the hydrostatic pressure of a liquid.

Hydrostatic Test. A hydrostatic test is a test to which tubing is sometimes subjected, consisting in subjecting it to an internal hydrostatic pressure.

Hygrometer. The hygrometer is an instrument for measuring the absolute or relative amount of moisture or humidity in the atmosphere. When the instrument is used only to determine changes in the humidity, it is termed a "hygroscope." The instrument depends usually upon the contraction or extension of certain substances when exposed to varying degrees of moisture. The contraction of a substance with an increase in humidity, for example, can be recorded on a scale, and thus indicate the relative amount of moisture in the atmosphere.

Hyperbola. The hyperbola is a geometrical curve formed by a plane which intersects a cone parallel to the axis of the cone; hence it has two open branches, each extending to infinity, the principal characteristic of which is that the difference between the distances from any point on the hyperbola to two points on its major axis, known as *foci*, is

Hyperbolic Logarithms. Hyperbolic, natural, or Napierian logarithms are used in many calculations, especially those involving the mean effective pressure in steam engine cylinders. The hyperbolic logarithms are usually designated "hyp. log." Sometimes hyperbolic logarithms are also designated "$\log_e$" and "Nap. log." To convert hyperbolic logarithms into common logarithms (having 10 for a base), multiply the hyperbolic logarithm by 0.43429. To convert a common logarithm to a hyperbolic logarithm, multiply the common logarithm by 2.30258. Hyperbolic logarithms are used extensively in higher mathematics.

Hyper-Eutectoid Steel. If the carbon content of steel exceeds about 0.90 per cent it will consist of pearlite plus free cementite and it is known as hyper-eutectoid. See Eutectoid Steels; also Steel, Constituents or Structure.

Hypocycloid. A hypocycloid is formed by the path of a point on the circumference of a circle which rolls on the inside of the periphery of another circle. This curve is used for part of the tooth shape of cycloidal gear teeth, part of the tooth shape being formed by an epicycloid, which is the curve formed by the path of a point on the circumference of a circle which rolls on the outside of the periphery of another circle.

Hypo-Eutectoid Steel. This is a steel which has a carbon content lower than about 0.90 per cent, and which is composed of ferrite and pearlite, the latter being an intimate mixture of ferrite (pure iron) and cementite (carbide of iron). See Eutectoid Steels; also Steel, Constituents or Structure.

Hypoid Gears. Hypoid gears are tapered gears with offset axes which, in general, look like spiral bevel gears. The tooth action of hypoid gears combines the rolling action of spiral bevel gears with a percentage of endwise sliding. The chief advantages of hypoid gears are noiseless operation, increased load-carrying capacity, the possibility of high reduction and low numbers of teeth, long life, and high efficiency. The axis of the pinion is offset from the axis of the gear by an amount that varies with the diameter and the ratio. The direction of offset determines the hand of the spiral. In rear-axle design, a pinion below center will have a left-hand spiral, while a pinion above center will have a right-hand spiral. The position below center is preferable for two reasons: First, the axial thrust resulting on the pinion on a forward drive is directed away from the gear, and heavy loads tend to move the pinion out of mesh rather than draw it in; Second, the contact between mating tooth surfaces is more intimate on the drive side.

Tooth Loads: In computing the tooth loads of a pair of hypoid gears, the circumferential or tangential tooth load P of the gear

at the center of the face may be determined from the known torque, and the pressure P_n or load normal to the tooth surface is then determined by dividing by the cosine of the normal pressure angle a and by the cosine of the spiral angle hg of the gear. Thus

$$\cos a \times \cos hg$$

This amount P_n is the total tooth load, or, in other words, the resultant of all components. It is noted that this total tooth load is only slightly larger than the effective circumferential or tangential tooth load P of the gear, for if we introduce as average amounts $a = 17\frac{1}{2}$ degrees and $hg = 8$ degrees, we obtain:

$P_n = 1.06\ P$ — an increase of 6 per cent.

In spiral bevel gears, the total tooth load P_n is considerably larger than the effective tangential tooth load. If a pressure angle of $17\frac{1}{2}$ degrees and a spiral angle of 35 degrees is assumed, the total load is as follows:

$P_n = 1.28\ P$ — an increase of 28 per cent, as compared with 6 per cent for hypoid gears.

Hysteresis. When the iron core of an electromagnet is magnetized by a current flowing first in one direction and then in the opposite direction, there is an energy loss known as hysteresis which take the form of heat. Thus after the iron has been magnetized by a current of electricity flowing in one direction, the iron will not, of itself, return to its normal condition, but requires additional energy to accomplish this, and, if a rapid reversal of magnetism takes place continuously, it will be found that a considerable amount of energy has been absorbed. The effect is especially noticeable in iron subjected to rapidly alternating magnetizing forces, as in generators and in transformers. It varies with the frequency and the 1.6th power of the intensity of induction. "Aging" is the term used for expressing the increase in hysteresis loss in core laminations of electrical machines from the continued magnetic reversals at comparatively high temperatures during commercial operation. To prevent aging, silicon steel containing from 2.5 to 4 per cent of silicon is used. This steel has a much lower hysteresis loss than ordinary carbon steel. It is extensively used in transformer cores.

I

I-Beam. A name indicating the shape of one of the standard structural sections which is widely used in building construction and for many other kinds of structures. See Structural Shapes.

Idler Gear. An idler or intermediate gear simply transmits motion from one gear to another but it has no effect on the speed ratio, or the number of revolutions made by a driven shaft in a given time. This would also hold true if there were several intermediate gears. An idler, however, does change the direction in which the driven gear revolves. When driving and driven gears are located on fixed centers and when their sizes must be varied to obtain different speed ratios, an adjustable idler may be used as an intermediate transmitting member.

Idler Pulley. Some belt drives have an idler pulley bearing against one side of the belt to take up slack and also increase the arc of contact, especially on the smaller pulley. The idler of a Lenix or short-center belt drive is mounted on a pivoted weighted arm, and the belt, which is given plenty of slack, is automatically maintained at constant tension. This feature, in conjunction with the increased arc of contact, lengthens the life of the belt and greatly increases its driving power. Idler pulleys (also called "mule pulleys") are also used in conjunction with right-angle or other belt drives where the change in direction makes it necessary to support and guide the belt over pulleys.

Ignition Temperatures. The temperature of ignition is the degree of temperature at which a substance will combine with oxygen at a rate sufficiently rapid to produce a flame. The temperature of ignition has often been regarded as the temperature at which chemical combination begins, but this is not correct, because chemical combination has begun before a flame appears. The following temperatures are required to ignite the different substances specified: Phosphorus, transparent, 120 degrees F.; bisulphide of carbon, 300 degrees F.; guncotton, 430 degrees F.; nitroglycerin, 490 degrees F.; phosphorus, amorphous, 500 degrees F.; rifle powder, 550 degrees F.; charcoal, 660 degrees F.; dry pine wood, 800 degrees F.; dry oak wood, 900 degrees F.; illuminating gas, 1110 degrees F.; benzine, 780 degrees F.; petroleum, 715 degrees F.; gas oil, 660 degrees F.; machine oil, 715 degrees F.; coal tars, 930 degrees F.; and benzol, 970 degrees F.

Illium. Illium is an acid-resisting alloy of the following composition: Nickel, 60.65 per cent; chromium, 21.07 per cent; copper, 6.42 per cent; molybdenum, 4.67 per cent; tungsten, 2.13 per cent; aluminum, 1.09 per cent; silicon, 1.04 per cent; manganese, 0.98 per cent; and iron, 0.76 per cent. Carbon and boron are also present in small quantities. The melting point is about 2400 degrees F. The tensile strength of the cast metal is approximately 50,000 pounds per square inch.

Illium-R. A corrosion-resistant alloy from which strip, welded tubing, and cold-rolled rods are produced having, when work-hardened, a tensile strength ranging from 140,000 to 150,000 pounds per square inch. In an annealed condition, the tensile strength is from 95,000 to 105,000 pounds per square inch. Brinell hardness, work-hardened, from 340 to 365; annealed, from 175 to 240. The alloy is of approximately the same machinability as stainless steel. Strip stock of Illium-R is available in a number of widths and lengths and in gages from 8 to 34; adapted for drawing, perforating, stamping, and other fabrication methods. Rolled rod is suitable for tie-rods, light shafting, screw machine stock, and small hardware.

Immersion Brazing. This is a brazing process in which the work to be brazed is immersed in liquid spelter solder. It is also known as Dip Brazing.

Impact Tests. Impact tests are made on materials in order to determine their ability to resist shock. A number of machines have been devised for measuring the resistance to impact. One of these, known as the *Charpy impact machine*, consists mainly of a swinging pendulum capable of delivering a blow having a total energy of 30 meter-kilograms (216.99 foot-pounds). The machine is operated by raising the pendulum to an angle of 155 degrees from its lower vertical position. The test specimens are made in the form of bars, 10 millimeters square by 60 millimeters long, notched to a depth of 5 millimeters at the center, the bottom of the notch having a radius of 0.667 millimeter. This test-bar is placed with the ends across knife-edges, the pendulum is released by means of a trigger, and the test specimen is literally chopped in two, after which the pendulum ascends to an angle depending upon the energy remaining after impact. This angle is registered on a scale. The weight of the pendulum and the height of its center of gravity, before impact, being known, the energy of the blow can be determined. The height of the center of gravity for the angle of ascension after impact being registered, the energy remaining in the pendulum after impact can be determined. The difference is the energy absorbed by the test specimen. This method of testing provides a comparative test of considerable accuracy.

Another type of machine subjects the material to a series of fatigue and impact fatigue tests in such a way that the test piece is not destroyed by one blow. The number of blows required to break a test piece are recorded on a counting device. Different kinds of steel vary greatly in the number of blows required to establish the breaking point, and for this reason the principle upon which the machine is based is a practical one for determining the homogeneity of the metal and its resistance to shock. The machine is set to deliver from 85 to 100 blows per minute. The ram, of a given weight, is raised by a cam driven from an electric motor, and then released to fall on the test piece. The number of blows required to break a test piece depends upon the quality of the material being tested, its structure and the heat-treatment that it has received.

Impedance. Impedance is an abbreviated expression for a certain combination of the electrical properties of a circuit. For example, in a circuit containing resistance and reactance:

$$\text{Impedance} = \sqrt{\text{resistance}^2 + \text{reactance}^2}.$$

The impedance of a portion of an electric circuit to a completely specified periodic current and potential difference is the ratio of the effective value of the potential difference between the terminals to the effective value of the current, there being no source of electromotive force in the portion under consideration.

Impeller. In a centrifugal pump, the impeller is the rotating element provided with vanes, which draws in air or liquid at the center and expels it at a high velocity at the periphery. There are two impellers in a rotary blower running in mesh with each other.

Imperial Bushel. One British Imperial bushel equals 8 Imperial gallons, equals 1.2837 cubic feet.

Imperial Gallon. This is a legal measure of capacity in Great Britain, and is defined as the volume of ten pounds of pure water at 62 degrees F., and equal to one-eighth of an Imperial bushel. The volume of the Imperial gallon equals 277.42 cubic inches, or approximately 1.2009 U. S. gallons.

Imperial Wire Gage. The Imperial wire gage is the standard British wire gage authorized by Order in Council, August 23, 1883, as the legal standard for Great Britain. It is also known as the "Standard wire gage" (abbreviated S.W.G.), as the "New British Standard wire gage" (abbreviated N.B.S.) and as the "British Legal Standard wire gage."

Incandescent Lamps. The incandescent lamp is based upon the principle that, when an electric current is sent through a conductor of high resistance, the conductor is heated. If the ma-

terial for the conductor, the current, the voltage, and other conditions are such that the conductor will be heated until it becomes incandescent and, hence, gives out light, this combination embodies the principle of the electric incandescent lamp. Carbon-filament lamps have been superseded largely by tungsten-filament lamps which are more efficient. Usually these filaments operate in a glass bulb which has a high vacuum or which is filled with a mixture of argon and nitrogen. This serves to increase the life of the filament which would soon burn out if exposed to oxygen. Incandescent lamps may be operated on either direct-current or alternating-current circuits, and either in multiple or series.

Operation of an incandescent lamp at voltage 10 per cent higher than rated may decrease its life by as much as 70 per cent, while operation at a voltage of 10 per cent lower than rated may decrease the light output by as much as 30 per cent. For most satisfactory results, the applied voltage should be maintained within 3 per cent of that rated for the lamp.

Inch. A unit of length measurement; 1 inch = 2.54 centimeters = 25.4 millimeters.

Inch, Circular. See Circular Inch.

Inch-Pound. Torsional tests are made to ascertain the elastic limit and the ultimate torsional strength. Since the strain varies over the sectional area, it is not possible to express the torsional strain as "pounds per square inch," but as "pound-inches" or "inch-pounds." The torsional or twisting moment in pound-inches is obtained by multiplying the pull applied by the lever arm through which it acts. For instance, assume that a wrench were gripped on a pipe; then, if a pull of 100 pounds is exerted on the wrench at a distance of 10 inches from the center of the pipe, the torsional strain on the pipe would be $10 \times 100 = 1000$ pound-inches. See also Pound-foot.

Inclinable Power Presses. Presses of the inclinable class are so designated from the fact that the upper part of the frame may be inclined to allow finished parts to slide from the die due to the action of gravity. This type of press may also be used with the inclinable member in the vertical position. Inclinable power presses are generally of the gap type. They are extensively used and are particularly adapted for blanking, piercing, forming, and shallow drawing operations on household utensils, small automobile parts, and many other articles, as well as light embossing operations on jewelry, etc. Presses of this type are generally built in sizes having capacities ranging from two to seventy-five tons. A press of greater capacity than the maximum mentioned would be so heavy as to be difficult to incline by means of the

hand-operated mechanism with which these presses are usually furnished.

The inclinable power press is particularly suitable for the automatic production of small parts when it is equipped with a feeding arrangement adapted to the part being produced. For the first operation on a given part the stock is usually fed to the dies in the form of a ribbon or strip by either a single- or a double-roll feed. Very high production rates can be obtained in this manner, it being frequently possible to produce completed or partly completed parts as the rate of 150 per minute. Other styles of feeds used for succeeding operations include dial, hopper, and finger mechanisms. *Inclined presses* have the frame built in a fixed, inclined position, and are thus non-adjustable.

Inclined Plane. A plane which makes an oblique angle with the horizontal and which is used to facilitate the moving of bodies, as in the case of a wedge, is classed as one of the "mechanical powers." If μ = coefficient of friction; a = angle of plane, W = weight of body to be moved along plane, and F = force required to move body; then if F acts parallel to the inclined plane and so as to pull the body upward, $F = W\ (\mu \cos a + \sin a)$. If the movement of the body is down the plane, then $F = W\ (\mu \cos a - \sin a)$. If the force acts parallel to the base of the plane, then $F = W \tan\ (a + \theta)$. The coefficient of friction $= \tan \theta$.

Incrustation. The incrustation or scale formed in a boiler, may be due either to the precipitation of mineral substances or to the settling of mud or earthy matter held in suspension by the feed water. See Boiler Scale.

Independent Chucks. Independent chucks usually have four radial jaws which are fitted in grooves or slots in the chuck body and are adjusted independently by means of screws that are turned by a chuck wrench.

Independent Crane. An independent crane is a jib crane the post of which is so pivoted in the floor foundation and at the top that it is free to make a complete circle about its pivots. This crane is suitable for use in the center of large bays in shops and foundries, as it can serve a wide area.

Indexing. The process of dividing a circular part into equal spaces or divisions by means of an indexing- or dividing-head is known as indexing. There are three systems of indexing known as the plain or simple system, the compound system, and the differential system.

Plain Indexing: When indexing, if the required division or movement can be obtained by simply turning the index-crank of

the indexing or dividing-head the required amount, and engaging it with one of the holes in the index plate, this is known as *plain* or *simple* indexing, because only one indexing movement is necessary, instead of two movements, as with compound indexing.

Compound Indexing: Ordinarily, the index-crank of a dividing-head must be rotated a fractional part of a revolution, when indexing, even if one or more complete turns are required. This fractional part of a turn is measured by moving the latch-pin a certain number of holes in one of the index circles; but, occasionally, none of the index plates furnished with the machine has circles of holes containing the necessary number for obtaining a certain division. One method of indexing for divisions which are beyond the range of those secured by the plain or simple method is to first turn the crank a definite amount in the regular way, and then the index plate itself, in order to locate the crank in the proper position. This is known as *compound* indexing, because there are two separate movements which are, in reality, two simple indexing operations. The index plate is normally kept from turning by a stationary stop-pin at the rear, which engages one of the index holes. When this stop-pin is withdrawn, the index plate can be turned.

Differential Indexing: This system is the same in principle as compound indexing, but differs from the latter in that the index plate is rotated by suitable gearing which connects it to the dividing-head spindle. This rotation or differential motion of the index plate takes place when the crank is turned, the plate moving either in the same direction as the crank or opposite to it, as may be required. The result is that the *actual* movement of the crank, at every indexing, is either greater or less than its movement with relation to the index plate. This method of turning the index plate by gearing instead of by hand makes it possible to obtain any division liable to arise in practice, by using one circle of holes and simply turning the index crank in one direction, the same as for plain indexing. In actual practice, the number of turns of the index-crank for obtaining different divisions is usually determined by referring to indexing tables.

Indexing Attachments. Attachments of this general type are used on milling machines whenever equally spaced grooves must be milled in such parts as cutters, reamers, gears, ratchets, etc. The indexing attachment is designed to hold the work and rotate it whatever fractional part of a turn is likely to be required. Attachments used for indexing may also be designed to rotate the work slowly and continuously in conjunction with the table-feeding movement for milling helical grooves in reamers, gears, etc. Several different names have been applied to indexing attachments, such, for example, as *index centers,* index or *index-*

ing head, dividing head, and *spiral head* when the attachment is designed both for indexing and helical or spiral milling.

The name index centers is based upon the fact that parts to be indexed usually are held between the centers of an index head and a foot-stock. The term *plain index centers* has been applied to a simple attachment designed merely for indexing or dividing. When there is angular adjustment of the index-head spindle, the term *universal index centers* may be used to distinguish such an attachment from the plain type which does not have the angular adjustment. The name *universal spiral index centers* is applied by at least one manufacturer to the type which may be used not only for indexing, but for rotating the work in helical milling. Such indexing attachments may also be known as dividing heads or as indexing heads.

Optical Dividing Head: The main feature of the optical dividing head is the means provided to insure accurate settings. There is a glass dial mounted directly on the spindle, and this dial is graduated to 360 degrees around the periphery. While indexing the spindle, the dial graduations may be observed through a microscope as the hand-wheel is being turned, and when the desired setting has been obtained, the spindle is locked in place. Readings are made directly in minutes. The spaces between the degree graduations of the glass dial are magnified sixty times by the microscopic eye-piece, and appear about 1¾ inches apart. A second vernier scale of 60 minutes is projected by the ocular into the field of observation, and, as the graduations on this scale appear about 0.03 inch apart, it is safe to estimate settings within 20 seconds.

Indexing, Block. See Block Indexing.

Indian Corundum. This is a natural abrasive obtained from India, which contains about 73 per cent of crystalline alumina, which constitutes the cutting material of the abrasive. As an abrasive, it is better than emery, but is not as good as the Canadian or Georgia abrasive.

Indian Steel. See Damascus Steel.

India-Rubber Cement. Same as Hart's india-rubber cement.

Indicated Horsepower. The actual power exerted by the expanding steam in the cylinder of a steam engine, or the power of the explosion and expansion of the gases in the cylinder of a gas or oil engine, is known as the *indicated* horsepower. The indicated horsepower does not take account of any frictional losses; hence, it is always greater than the brake horsepower. Indicated horsepower is so named because the amount of power developed in the cylinder per stroke is determined by getting the mean effective or average pressure throughout the stroke, from an

indicator diagram obtained with an engine indicator. See also Horsepower.

Indicator Diagrams. A diagram may be made to represent graphically the work done in an engine cylinder during one stroke of the piston. An indicator is a device for making a diagram of what actually takes place in an engine cylinder under working conditions. Such a diagram taken from a steam engine cylinder, shows the points of admission, cut-off, and release, and indicates accurately the pressures acting on both sides of the piston at all points of the stroke. The indicator diagram provides means of determining the mean effective pressure, from which the indicated horsepower of the engine can be determined. Such diagrams, taken from engines in service, also show any defects in steam distribution due to improper valve setting. Just how an indicator diagram represents the work done in an engine cylinder will be apparent by considering first the ideal or "work diagram."

Work Diagram: One of the first steps in the design of a steam engine is the construction of an ideal diagram, and the engine is planned to produce this as nearly as possible when in operation. First assume the initial pressure, the ratio of expansion, and the percentage of clearance, for the type of engine under consideration. Draw lines *OX* and *OY* at right angles. (See Fig. 1.) Make *OR* the same percentage of the stroke that the clearance is of the piston displacement; make *RX* equal to the length of the stroke (on a reduced scale). Erect the perpendicular *RA* of such a height that it shall represent, to scale, an absolute pressure per square inch equal to 0.95 of the boiler pressure. Draw in the dotted lines *AK* and *KX*, and the atmospheric line *LH* at a height above *OX* to represent 14.7 pounds per square inch. Locate the point of cut-off, *B*, according to the assumed ratio of expansion. Points on the expansion curve *BC* are found as follows: Divide the distance *BK* into any number of equal spaces, as shown by *a, b, c, d,* etc., and connect them with the point *O*. Through the points of intersection with *BP*, as *a′, b′, c′, d′*, etc., draw horizontal lines, and through *a, b, c, d,* etc., draw vertical lines. The intersection of corresponding horizontal and vertical lines will be points on the theoretical expansion line. If the engine is to be non-condensing, the theoretical work, or indicator diagram, as it is called, will be bounded by the lines *ABC HG*.

Indicator Diagram: The actual diagram obtained with an engine indicator, will vary somewhat from the theoretical, as shown by the shaded lines. The admission line between *A* and *B* (Fig. 1) will slant downward slightly, and the point of cut-off will be rounded, owing to the slow closing of the valve. The first half of the expansion line will fall below the theoretical, owing to a drop in pressure caused by cylinder condensation, but the actual line

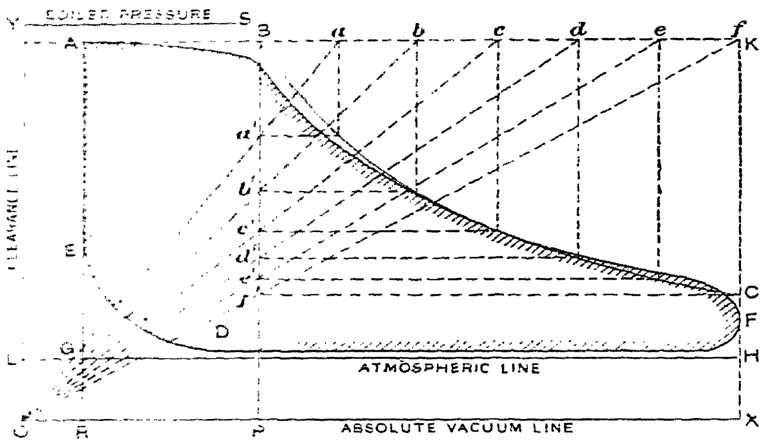


Fig. 1. Construction of a Steam Engine Work Diagram

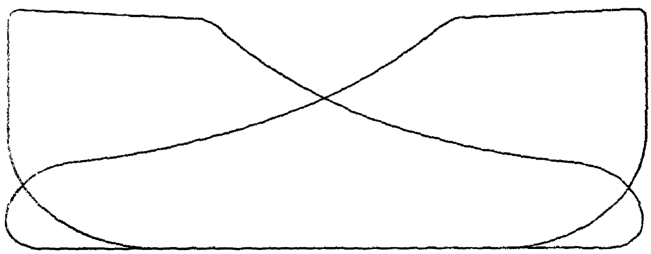


Fig. 2. Typical Indicator Diagrams

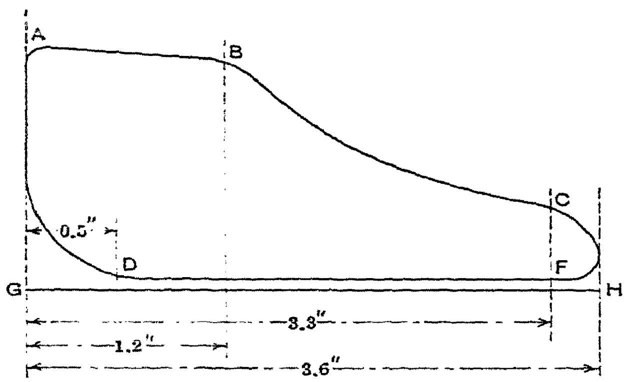


Fig. 3. Diagram for Illustrating Method of Computing Cut-off, Compression and Mean Pressure

will rise above the theoretical in the latter part of the stroke on account of reevaporation, due to heat given out by the hot cylinder walls to the low-pressure steam. Instead of the pressure dropping abruptly at *C*, release takes place just before the end of the stroke, and the diagram is rounded at *CF* instead of having sharp corners. The back pressure line *FD* is drawn slightly above the atmospheric line, a distance to represent about 2 pounds per square inch. At *D* the exhaust valve closes and compression begins, rounding the bottom of the diagram up to *E*. The area of the actual diagram, as outlined by the shaded lines, will be smaller than the theoretical, in about the following ratio: Large medium-speed engines, 0.90 of theoretical area; small medium-speed engines, 0.85 of theoretical area; high-speed engines, 0.75 of theoretical area. Diagrams for both ends of the engine cylinder are usually on one card as shown by Fig. 2. It is simpler to take them both on the same card, and also easier to compare the working of the two ends of the cylinder. The analysis of a card for practical purposes is shown in Fig. 3. Suppose, for example, that the length of the diagram measures 3.6 inches; the distance to the point of cut-off is 1.2 inches; and the distance to the point of release is 3.3 inches. Then, by dividing 1.2 by 3.6, the cut-off is found to occur at $1.2 \div 3.6 = 1/3$ of the stroke. Release occurs at $3.3 \div 3.6 = 0.92$ of the stroke. Compression begins at $(3.6 - 0.5) \div 3.6 = 0.86$ of the stroke. The diagrams shown in Figs. 2 and 3 are from non-condensing engines, and the back-pressure line is, therefore, above the atmospheric line, as indicated.

Mean Effective Pressure: The method of determining the mean effective pressure is as follows: First measure the area of the card in square inches, by means of a planimeter, and divide this area by the length in inches. This gives the mean ordinate; the mean ordinate, in turn, multiplied by the strength of the spring used, will give the mean effective pressure in pounds per square inch. For example, suppose that the card shown in Fig. 3 is taken with an indicator having a 60-pound spring, and that the area, as measured by a planimeter, is found to be 2.6 square inches. Dividing the area by the length gives $2.6 \div 3.6 = 0.722$ inch as the mean ordinate, and this multiplied by the strength of spring gives a mean effective pressure of $0.722 \times 60 = 43.3$ pounds per square inch.

In practice, diagrams taken from the two ends of the cylinder usually vary more or less, due to inequalities in the valve action. Again, the effective area of the piston on the crank end is less than that on the head end, by an amount equal to the area of the piston-rod. For these reasons, it is customary to compute the mean effective pressure of all the cards separately, and take, for

use in the horsepower formula, the average of the various computations.

Indicator Diagram from Air Compressor: Fig. 4 represents a typical indicator card from an air compressor cylinder; *MN* is the atmospheric pressure line; the piston displacement is denoted by V and the clearance volume by V_c. During the suction stroke, air is drawn into the cylinder along the suction line *DC*. The pressure p_s inside the cylinder during the suction stroke must necessarily be less than the atmospheric pressure, or there would be no flow of air into the cylinder. At *C* the cylinder is full of air at pressure p_s, and the piston on its return stroke compresses this air along line *CB*. At point *B* the discharge valves open and the volume of high-pressure air in the cylinder is driven out

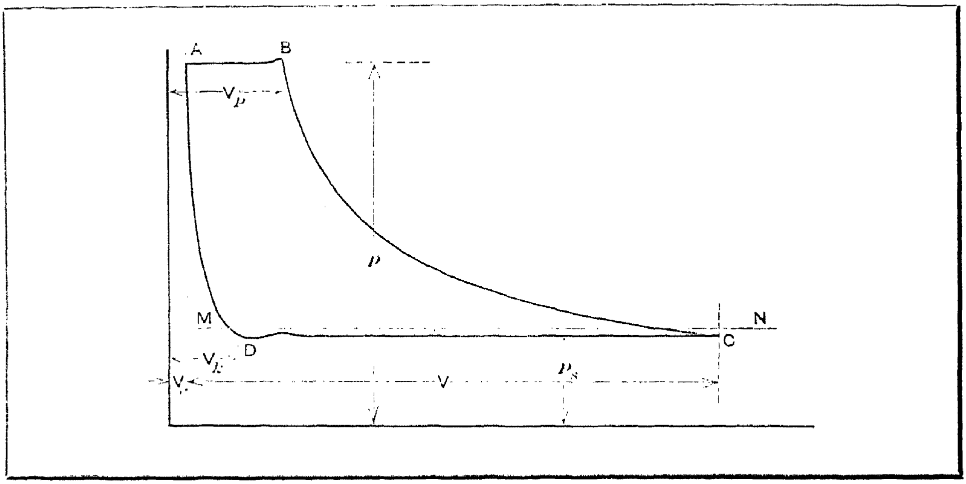


Fig. 4. Typical Air Compressor Diagram

along the line *BA* until at the end of the stroke, at *A*, only the clearance volume, V_c, is filled with air at the pressure p. On the suction stroke, no air can be drawn into the cylinder until this clearance air has expanded so that its pressure drops to p_s, less than atmospheric pressure, thus allowing the suction valves to open. For simplicity, the slight additional drop in pressure indicated by the wavy line at *D*, necessary to overcome the inertia of the suction valves, is disregarded.

The assumption that the volume of free air drawn into the compressor per minute is equal to the piston displacement could only be true in a cylinder having no clearance volume, and also where the temperature and pressure of the air on the suction side of the piston are the same as the temperature and pressure of the atmosphere.

In order to cause a flow of air into the suction end of the cylinder, the pressure p_s must be less than atmospheric pressure, as previously mentioned; therefore, the air expands as its pressure drops in entering the cylinder, and the original volume of the free air drawn in is less than the volume occupied by this air after it is in the cylinder. Furthermore, the temperature of the air inside the suction end of the cylinder is higher than the atmospheric temperature, since the air is heated as it enters, by contact with the walls of the cylinder left warm by the previous compression stroke. This also causes expansion and still further diminishes the volume of outside air required to fill the suction space.

Indium. A rare metallic chemical element (symbol In) found combined in small quantities in many ores, especially zinc blende. It is a soft, ductile metal with a "whiter" color than tin and the atomic weight is 114.76. Indium has a melting point of 155 degrees C. and is not easily oxidized. It has found application as a plating for bearings in airplane motors as it has great corrosion resistance, particularly against lubricants and acids. When so used indium is first electroplated on a base of cadmium, silver and copper and is then diffused into this base by heating.

Induced Draft. The induced draft system of a power plant has a fan placed between the furnace and the chimney, and the air is drawn through the furnace by suction. This corresponds with the natural draft produced by a chimney, and also permits of the use of an economizer in the main smoke connection. With this arrangement, all leakage is inward and there is no danger of dust and smoke being blown into the fire-room, as with forced draft. On the other hand, a system of induced draft is more expensive to install, because the gases, being at a higher temperature, have a greater volume, and require a higher speed and more power to move them.

Inductance. The term *inductance* is used to denote the property of an electric circuit (or circuit element such as a coil), or of two neighboring circuits (or circuit elements), which determines the electromotive force induced in one of the circuits or elements by a change of current in either of them. The unit of inductance is the *henry*.

Inductance Unit. See Henry.

Induction. Induction, in electricity, is the phenomenon by which a body charged with electricity or magnetism, or conducting an electric current, produces an electric or magnetic condition in a neighboring body without direct contact. "Electrostatic induction" is the production of an electrical charge in a body by

the influence of another body which is charged with static electricity. "Electrodynamic induction" is the production of an electromotive force in another circuit by the influence of a change in electric current. When the current is induced by the action of a magnet, or when a magnetic condition is induced by an electric current, the phenomenon is known as "electro-magnetic induction." "Magnetic induction" is the production of a magnetic condition in a magnetic substance by another magnet.

Induction Clutch. The induction clutch is similar in its operation to an induction motor. The induction clutch transmits power without contact between its driving and driven members.

Induction Coil. An induction coil, sometimes called a spark coil, is a device which is used to obtain a high alternating electromotive force from a low direct electromotive force. There are two types: The primary or single-coil type and the secondary or two-coil type, sometimes called *Ruhmkorff coil.* In the primary type, the coil is wound around a soft iron core and some form of interrupter and battery are placed in series with it. Every time the circuit is interrupted, the rapid decrease in current flow causes a high induced electromotive force which causes a spark to jump across the open contacts of the interrupter. This type of coil was at one time used for gasoline engine ignition, with the make and break unit located inside the cylinder. Since it is not suitable for high-compression engines or for operation at high speed, it has been replaced by the secondary type.

In the secondary type, two coils are used which are generally wound on a silicon-steel core. The primary winding consists of a relatively small number of turns and this winding is placed in series with the source of power which, when used for gasoline engine ignition, is usually a storage battery connected in parallel with a charging generator, and also in series with a circuit interrupter. The secondary is made up of a large number of turns of wire and is connected with the distributor and the various spark plugs. Here, again, interruption of the direct current in the primary coil induces a high voltage which is stepped up by transformer action in the secondary and causes a flow of current across the various spark plug gaps as they are connected sequentially in the circuit by the distributor.

Induction Hardening. See Tocco Hardening Process.

Induction Motors, Polyphase. Commercial induction motors have a stationary element called the "stator," and a rotating element called the "rotor." The induction motor derives its name from the fact that the secondary member or rotor receives its electrical energy from the primary member or stator by magnetic induction, there being no electrical connection between the stator

and rotor windings. The transformer is the most commonly known piece of electrical apparatus, in which one winding receives its electrical energy from a second and independent winding by magnetic induction; hence, it is common practice to consider an induction motor as a transformer with a stationary primary and a revolving secondary. Thus, the stator is often called the "primary," and the rotor, the "secondary." The windings are so placed in the stator slots as to cause a rotating magnetic field to be produced when alternating current is supplied. The rotor of an electric induction motor must revolve at a speed somewhat lower than synchronous, in order that a secondary current and a torque shall be created. The actual speed of an induction motor is, therefore, less than the synchronous speed by a few per cent, called the "per cent slip." The slip increases with the load, thus increasing, by the cutting of lines of force, the current in both secondary and primary windings, and the torque.

Squirrel-Cage Induction Motors: This is the simplest type of induction motor and is most commonly used for constant-speed, general-purpose work. A series of copper or aluminum bars fitted into slots in the rotor core and rigidly connected at each end to a continuous ring constitutes the "squirrel-cage" rotor winding from which the motor takes its name.

Wound-Rotor Induction Motors: This type of induction motor is used where starting must be accomplished under extremely heavy loads or where smooth speed acceleration is needed as in hoists, cranes, or conveyors. In addition to a squirrel-cage winding, a number of form-wound coils are used as an auxiliary rotor winding, and these are connected to three collector rings. The currents induced in this winding, when the motor is connected to the line, pass through brushes bearing on these rings to an external variable-resistance control which governs starting and running speeds.

High-Frequency Induction Motors: This type of induction motor is of the same general construction as the standard squirrel-cage motor but is designed to operate at higher frequencies. A speed of 3600 revolutions per minute is the maximum that can be obtained with ordinary 60-cycle motors. These high frequency motors are, on the other hand, high-speed motors with speeds ranging, ordinarily, from 3600 to 18,000 revolutions per minute. Still higher speeds are feasible.

The established frequency and voltage ranges for which they are designed are:

1. Normal-frequency series with a frequency range from 60 cycles at 220 volts to 100 cycles at 367 volts maximum.
2. First high-frequency series with a frequency range of 120 cycles at 220 volts up to 199 cycles at 367 volts, or

down to 60 cycles at 110 volts. Or 120 cycles at 440 volts up to 150 cycles at 550 volts or down to 60 cycles at 220 volts.

3. Second high-frequency series with a frequency range of 200 cycles at 110 volts up to 540 cycles at 297 volts or down to 180 cycles at 99 volts.
4. Portable-hand-tool series with frequencies of 175 or 180 cycles.

The development of the high-speed induction motor for direct application to machine tools has been of great importance to the machine tool industry. Moderate and high-speed motors are now applied to the same machine, the high-speed motor generally being used to drive the cutting tool, and the slower speed motor to drive the feeding mechanism.

Induction Motors, Single Phase. See Single Phase Motors.

Induction Pipe. The name "induction pipe" is sometimes given to the pipe through which the live steam passes to the steam chest of a steam engine. The opening from the steam chest into the cylinder through which the live steam flows is known as the *induction port.* The *induction valve* is the valve controlling the supply of live steam to the cylinder.

Induction Regulator. An induction regulator is a form of transformer, the secondary voltage of which may be varied from maximum to zero and then to maximum in the opposite direction, by changing the relative angular position of the primary and secondary. The induction regulator is used to maintain constant voltage on circuits where constant voltage is important, such as lighting circuits, the varying load of which makes such a device necessary. A small variation in the voltage of a lighting circuit makes a large variation in the luminosity of the lamps, and close regulation is important. The primary is connected across the line and the secondary is connected in series with the line. This type of regulator gives a perfectly smooth change without steps.

Inertia, Moment of. See Moment of Inertia; also Polar Moment of Inertia.

IngOclad. A material consisting of a sheet of mild carbon steel with a thin sheet of stainless steel welded to it. Combines the non-corrosive properties of stainless steel with the low cost of carbon steel. Used for cooking utensils, shower-bath compartments, beer barrels, milk storage tanks, etc.

Ingots. After a large body of steel has been refined in an open-hearth furnace or Bessemer converter, it is common practice to pour the molten steel into cast-iron molds thus forming ingots of convenient size for subsequent rolling or forging operations.

In *bottom-pouring* an ingot, the metal is poured into a vertical

runner and flows up into the mold through an opening in the bottom. As the runner is kept full of metal by the constant flow from the ladle, the level in the ingot mold gradually rises. While all metallurgists and steel makers do not agree that bottom-poured ingots possess the superior qualities which others claim for them, the principal advantages from this method of pouring may be summarized as follows: The metal flows up into the mold very quietly and without any splashing such as occurs when pouring from the top and especially when first beginning to pour into the bottom of the mold. This splashing action which accompanies top-pouring results in a poor surface condition of the ingot. It is also claimed that when pouring from the bottom there is less tendency to entrap dirt or foreign matter in the ingot, as this is carried outward to the surface of the mold when the metal flows up through the opening in the center. Still another advantage claimed for the bottom method of pouring is that there is practically no oxidizing action of the air upon the stream of metal which flows from the ladle. The distance between the bottom of the ladle and the top of the runner is only a few inches, so that there is no time for oxidizing action to occur, which is not the case when the metal is poured from the top and there is a long stream extending from the ladle to the level of the metal in the ingot. Some metallurgists contend that the advantages which might accrue from bottom-pouring are partially, if not entirely, offset by a slagging off of the refractory lining in the runner; others claim that such slagging action can be reduced until it is negligible.

Inhibitors. In the pickling of steel in sulphuric acid, the steel itself is attacked after the scale is removed. To prevent or to reduce this attack to a minimum, a class of addition agents has been developed that are called "inhibitors." The inhibitor covers the steel after the scale has been removed and prevents a further attack of the base metal by the acid.

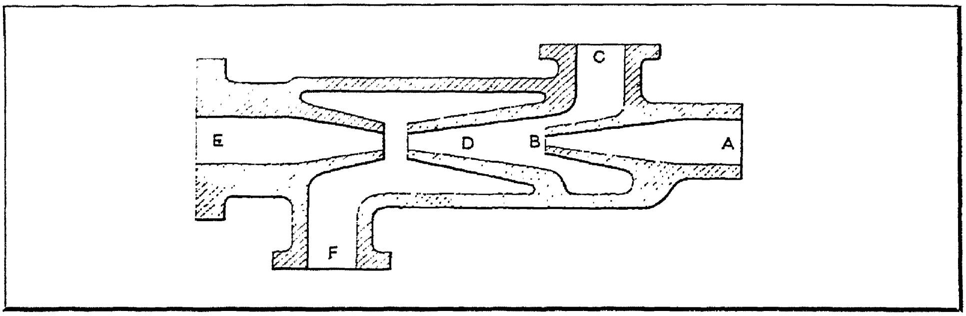
Initial Pressure. The pressure in the cylinder of a steam engine up to the point of cut-off, is called the initial pressure. It is usually slightly less than boiler pressure owing to "wire-drawing" in the steam pipe and ports.

In air compressors the initial pressure is the pressure from which the air is compressed to a higher pressure. The initial pressure is usually the atmospheric pressure.

Initial Volume. In air compression, the initial volume is the volume of the air before it has been compressed. This is usually the volume of the air at atmospheric pressure.

Injector. The injector is a device for feeding water to steam boilers, the steam of the boiler itself being used to force water

into the boiler against its own pressure. The diagram shows the elementary principle of the action of an injector. The steam from the boiler enters at *A* and passes through the orifice *B;* the feed water enters through *C* into a chamber which entirely surrounds the steam nozzle. When the stream strikes the feed water, it is condensed, and a vacuum is produced in the chamber *D;* hence, the water is forced with great velocity into and through this chamber, its velocity being increased by the pressure of the steam entering at *B*. When the water expands in the lower part of the nozzle at *E*, it loses velocity, but, according to the laws of hydrodynamics, it gains in pressure, so that it can enter the boiler through a check-valve. The pipe at *F* is an overflow, providing an outlet for the steam and water until the velocity and pressure acquired is great enough to force the water into the boiler.



Principle of Injector Action

Inspection Gages. Inspection gages are used by the inspector for checking the product. These gages are generally of the same design as the working gages, except that they have a smaller allowance for wear. See Gage Classification.

Inspirator. The inspirator is a device consisting of two combined injectors or a double injector used in connection with a steam boiler. One injector is used for raising the feed water for the boiler from a reservoir and delivering it to the other injector, which forces it into the boiler.

Instrument Metal. For certain classes of scientific and other instruments, it is important to use a metal which has a very small coefficient of expansion. A nickel steel alloy known as Invar is adapted to work of this kind. See Invar; also Platinite.

Instrument Threads. The standard instrument thread employed by the Royal Microscopical Society of London, England (sometimes known as the "Society" thread), is used for microscope objectives and the nose-pieces of the microscope into which

these objectives screw. The form of the thread is the standard Whitworth form. The number of threads per inch is 36. There is one size only. The maximum pitch diameter of the objective is 0.7804 inch and the minimum pitch diameter of the nose-piece is 0.7822 inch. The Royal Photographic Society Standard Screw Thread ranges from 1-inch diameter upward. For screws less than 1 inch, the Microscopical Society Standard is used. The British Association thread is another thread system employed on instruments abroad.

Insulation, Heat. The best insulating materials for preventing loss of heat in steam or hot water pipes are those that hold air confined in minute cells. Incombustible mineral substances are to be preferred to combustible material. No covering should be less than one inch in thickness. Mineral wool, a fibrous material made from blast furnace slag, is an excellent noncombustible covering, but it is brittle and, therefore, likely to be reduced to a powder when subjected to vibration. The percentage of steam lost through a covering of mineral wool about 1¼ inches thick is about one-tenth of that lost from bare pipes. A heat insulation composed of a number of layers of asbestos paper in which are imbedded small pieces of sponge is also very effective. The amount of heat lost with the general commercial pipe coverings is from one-eighth to one-sixth of the amount that would be lost with bare pipes. In most cases, it pays to use the best commercial pipe covering obtainable, because often the material is paid for many times over during the first year by the saving effected by its use. Few steam lines at the present time are provided with a covering thick enough for the greatest net saving. However, where fuel is cheap and the lines are in use only a small percentage of the time, the thinner coverings have their advantages. Also, there are places, as on some heating systems, where the heat lost through the coverings is not wasted. Therefore, a careful study of conditions is necessary before a certain type of covering can be recommended. The durability of materials used for pipe coverings is also an important factor in determining the most economical covering for a given set of conditions. The proper basis for comparing costs is the cost per year and not the first cost of the material.

Insulation, Thermal Classification. For purposes of assigning definite permissible temperature limits to the insulation in motors and generators, and other electrical equipment, according to the material used therein, the following classification has been established as an American Institute of Electrical Engineers Standard.

Class O insulation consists of cotton, silk, paper, and similar

organic materials when neither impregnated nor immersed in a liquid dielectric.

Class A insulation consists of (1) cotton, silk, paper, and similar organic materials when either impregnated or immersed in a liquid dielectric; (2) molded and laminated materials with cellulose filler, phenolic resins and other resins of similar properties; (3) films and sheets of cellulose acetate and other cellulose derivatives of similar properties; and (4) varnishes (enamel) as applied to conductors.

Class B insulation consists of mica, asbestos, fiber glass and similar inorganic materials in built-up form with organic binding substances. A small proportion of Class A materials may be used for structural purposes only.

Class C insulation consists entirely of mica, porcelain, glass, quartz and similar inorganic materials.

As used in the Class A definition, an insulation is considered to be "impregnated" when a suitable substance replaces the air between its fibers, even if this substance does not completely fill the spaces between the insulated conductors. The impregnating substances in order to be considered suitable, must have good insulating properties; must entirely cover the fibers and render them adherent to each other and to the conductor; must not produce interstices within itself as a consequence of evaporation of the solvent or through any other cause; must not flow during the operation of the machine at full working load or at the temperature limit specified; and must not unduly deteriorate under prolonged action of heat.

The electrical and mechanical properties of the insulated winding must not be impaired by application of the temperature permitted for Class B material. (The word "impair" is here used in the sense of causing any change which could disqualify the insulating material for continuous service.) The temperature endurance of different Class B insulation assemblies varies over a considerable range, in accordance with the percentage of Class A materials employed, and the degree of dependence placed on the organic binder for maintaining the structural integrity of the insulation.

Insulators, Electrical. Materials whose electrical conductivity is so low that the flow of current through them can usually be neglected under ordinary conditions are known as insulators and comprise a large number of natural and synthetic substances, varying widely in composition and physical properties. In some instances, insulating materials are required which are highly heat-resistant or arc-proof, as finger shields or arc deflectors in controllers, heating device insulation, etc., whereas in other cases the insulating material must become liquid or soft, or self-healing

under heating or arcing, as in high-tension bushings. A definite amount of wear under abrasion is required in certain construction, as in commutators and magneto distributors, but in other cases, there must be a minimum of abrasive wear, as in rheostat dead segments, wire insulation, etc. Heat conductivity is an important requirement in some instances, as in armature coils, but in other insulation, as in heating devices, a minimum heat conductivity gives greatest efficiency. It is obvious, therefore, that in insulating work diametrically opposite properties are often required in the materials used. It is because of the necessity of meeting these varied requirements that large numbers of insulating materials are now employed in the electrical industry and new materials are constantly being developed.

Porcelain: Porcelain is comparatively inexpensive, chemically inert, and not sensitive to temperature changes. It can be accurately molded or formed to a variety of shapes. There are two main types of porcelain used for electrical insulation: Dry-processed porcelain which is porous and usually suitable only for low-voltage applications, and wet-processed porcelain which is non-porous and used for high-voltage applications.

Lava: Ceramic materials of the so-called lava type, such as steatite, cordierite, rutile, and pyrophyllite, have assumed increasing importance as electrical insulators. Some of these have low power factor at high frequencies, others are highly resistant to thermal shock while still others have a high dielectric constant and low dielectric loss.

Glass: Glass for insulating purposes, like porcelain, is heat and water resistant, unaffected by oils and vapors, and high in crushing strength. Recently developed is a glass fiber material which can be woven into a fabric for wire or coil insulation. When impregnated with varnish, it has excellent insulation resistance at high humidity and also at high temperature. It is receiving increased attention as a motor insulation for severe duty.

Mica: Mica comprises a group of natural silicates distinguished by highly developed basic cleavage into thin, tough, flexible laminae. Mica is especially valuable for commutator insulation because of its evenly laminated structure, resistance to compression, mechanical toughness, resistance to high temperature, and insolubility. White mica is used for undercut commutator insulation, while amber mica, which is softer, is used for flush commutator insulation. Amber mica is also used in heating appliance insulation because of its resistance to higher temperatures. Mica is also used as a sheet insulation with some type of insulating paper or cloth backing.

Marble, Slate and Soapstone: These materials have found general use in slab or plate form for switchboard panels, small switch

bases, etc. Soapstone is also machined to form small bushings, beads, and other insulating parts. Their use has, however, greatly declined with the advent of newer materials.

Molded Compounds: Synthetic plastics probably constitute the largest class of new insulating materials, and an almost endless variety of combinations of properties can be obtained uniting appearance and mechanical advantages with the desired electrical characteristics. Some of the types of synthetic plastics used as insulating material are:

Phenolic Formaldehyde: There are a number of kinds of this type of plastic having a wide range of characteristics, such as high heat resistance, good flexural strength, and excellent solvent resistance.

Cellulose Acetate: This material has good color possibilities and good solvent resistance.

Polystyrene: This material has excellent water, acid and caustic resistance, low loss factor, high resistivity and dielectric strength, and high heat insulation value.

Methyl Methacrylate: This material has good acid, caustic and solvent resistance, good heat insulation value, and high dielectric strength.

Ethyl Cellulose: This material has good caustic and solvent resistance, excellent dielectric strength and resistivity, low loss factor, and a high flexural strength which has made it particularly useful as a substitute for enamel on magnet wire.

Urea: This material has high flexural and tensile strength, low loss factor, excellent resistivity, dielectric strength and color possibilities.

Rubber and Rubber Synthetics: Natural rubber has long been used as electrical insulation material. In molded form, it is applied to wire and cable, and, as hard rubber, is also used in a variety of rigid shapes and forms. Synthetic rubber products have recently come to the fore in insulation applications where natural rubber is unsuitable, as, for example, in wire insulation where exposure to oil or ozone produced by corona is anticipated.

Sheet Material: These include various papers, such as so-called fish paper which has a cotton rag base, fullerboard, Kraft paper, rope paper, cellophane, varnish-treated cloth, vulcanized fiber, and laminated phenolic compounds. The papers and cloths are used in plain and impregnated forms for the insulation of coils, while the fiber and laminated phenolic sheets are utilized where a strong, tough and more or less rigid material is needed.

Waxes: Several types of wax are used as impregnating materials for fibrous insulation, such as that used in paper condensers to improve moisture-resisting characteristics.

Oils and Varnishes: One of the most important types of in-

sulating materials used in the construction of motors, generators, and other coil-wound equipment, is varnish. It is particularly valuable as an impregnant and protective coating material to be applied after the forming of coils. It is also widely used in the manufacture of various tapes, sleevings and cloths, such as varnished fabric and fiber glass. A variety of types are available for air-drying or oven-drying. Enamel is also used as an insulating material, and one of its most common applications is for magnet wire insulation.

Oils are used extensively as an insulation for transformers and various types of switchgear where arcing is reduced by its presence. Synthetic oils have been introduced which are superior to mineral oils in some respects, such as inflammability.

Gases: While still in the early stages of development, the use of inert gas as an insulating medium has been found to be practicable — as in power cables, for example. In one instance, 100 pounds of gas of a type similar to that used as a refrigerant was found to provide the dielectric strength of 12,000 pounds of conventional insulating oil.

Intensifier. An intensifier is a hydraulic accumulator consisting of two cylinders of different diameters, the smaller cylinder being contained in the ram or plunger that fits into the larger cylinder. By the use of this machine very high pressures can be obtained.

Interchangeable Manufacture. In 1798, Eli Whitney, inventor of the cotton gin, obtained a contract from the government for 10,000 muskets, built a shop in the outskirts of New Haven, and there laid the foundations of the interchangeable system of manufacture. Using limit-gages, milling machines, and rude jigs, he demonstrated that guns could be manufactured by machine tools, not only interchangeably but more cheaply than by the old hand methods. About the same time, Simeon North, a gun-maker in Middletown, Conn., obtained contracts for pistols, and began a connection with the government which lasted for fifty years. A later contract signed by him in 1813 contained the first clause specifying interchangeability; "the component parts of pistols are to correspond so exactly that any limb or part of one pistol may be fitted to any other pistol of the 20,000." It is probable that the North contract of 1813 was not so much the beginning of the new method as the recognition of one which had already come into existence, as the letters of Whitney himself and the reports of Capt. Wadsworth, the government inspector, show clearly that Whitney, at least, had been developing the idea from 1798. The armory which he founded continued in business for ninety years, when it was sold to the Winchester Repeating Arms Co.

There are several degrees of interchangeability in machinery manufacture. Strictly speaking, interchangeability consists in making the different parts of a mechanism so uniform in size and contour that each part of a certain model will fit any mating part of the same model, regardless of the lot to which it belongs or when it was made. However, as often defined, interchangeability consists in making each part fit any mating part in a certain series; that is, the interchangeability exists only in the same series. Selective assembly is sometimes termed interchangeability, but is merely assembly without fitting. It will be noted that the strict definition of interchangeability does not imply that the parts must always be assembled without hand work, although that is usually considered desirable. It does mean, however, that when the mating parts are finished, by whatever process, they must assemble and function properly, without fitting individual parts one to the other.

When a machine has been installed possibly at some distant point, a broken part can readily be replaced by a new one sent by the manufacturer, but this feature is secondary as compared with the increased efficiency in manufacturing on an interchangeable basis. In order to make parts interchangeable, it is necessary to use gages and measuring tools, to provide some system of inspection, and to adopt suitable tolerances or limits. Whether absolute interchangeability is practicable or not may depend upon the tolerances adopted, the relation between the different parts, and their form. Parts will always interchange if the tolerances are large enough, and the maximum sizes of members such as shafts, etc., do not exceed the minimum sizes of holes which receive them when the machine is assembled; but if the tolerances are too large, the parts may be useless.

Intercoolers for Compressed Air. In compressing air, a great amount of heat is generated due to the friction of the molecules composing the air, which are being crowded into a small space. In compressing air to 100 pounds gage pressure, the final temperature, assuming the compression to be adiabatic, would be about 485 degrees F. The effect of this constant increase in temperature is to tend to expand the air under compression to a larger volume, thus necessitating a corresponding increase of work to compress this apparently increased volume. After the compressed air has been discharged into the receiver or pipe line, the temperature rapidly falls to that of the surrounding atmosphere and the energy due to the heat generated during compression is lost. It, therefore, follows that in compressing air to any great extent, a large amount of work is expended due to temperature conditions, and the only method of reducing to a minimum the amount of work lost is to cool the air during the period

of compression. In theory, the air should be kept at a constant temperature during the period of compression; but the attainment of this is a practical impossibility in air compressors. In modern practice, the work of compression is divided equally between two or more stages. The number of stages depends upon the final air pressure required. An "intercooler" is used between the different stages to reduce the temperature of the compressed air to the normal between the stages. An intercooler built in accordance with modern practice consists of a long shell of cylindrical shape containing a nest of tubes through which cold water is circulated. The air enters at one end of the shell from the low-pressure cylinder at a high temperature, passes around and between the nest of tubes, and enters the high-pressure cylinder at the other end at a greatly reduced temperature.

Interference Bands. See Light Wave Measuring Method.

Interferometer. The interferometer is an instrument of great precision for measuring exceedingly small movements, distances, or displacements, by means of the interference of two beams of light. Instruments of this type are used by physicists and by the makers of astronomical instruments requiring great accuracy. Prior to the introduction of the interferometer, the compound microscope had to be used in connection with very delicate measurements of length. The microscope, however, could not be used for objects smaller than one-half a wave length of light. Two physicists (Professors Michelson and Morley) developed an instrument which was named the *interferometer*, for accomplishing in the laboratory what was beyond the range of the compound microscope. This instrument consisted principally of a system of optical mirrors arranged in such a way as to let the waves of light from a suitable source pass between and through them, the waves in the course of their travel being divided and reflected a certain number of times, thus making it possible to measure objects ten times smaller than was possible with the best compound microscope obtainable. Professor C. W. Chamberlain of Denison University invented another instrument known as the *compound interferometer* which is much more sensitive than the one previously referred to; in fact, it is claimed that it will measure a distance as small as one twenty-millionth of an inch. These compound interferometers have been constructed in several different forms.

An important practical application of the interferometer is in measuring precision gages by a fundamental method of measurement. The use of this optical apparatus is a scientific undertaking, requiring considerable time and involving complex calculations. For this reason all commercial methods of checking accuracy must be comparative, and the taking of fundamental

measurements is necessarily confined to the basic or primary standards, such as are used to a very limited extent for checking working masters, where the greatest possible degree of accuracy is required. The interferometer is used to assist in determining the number of light waves of known wave length (or color) which at a given instant are between two planes coinciding with the opposite faces of a gage-block or whatever part is to be measured. When this number is known, the thickness can be computed because the lengths of the light waves used have been determined with almost absolute precision. The light, therefore, becomes a scale with divisions — approximately two hundred-thousandths inch apart.

Interlocking Safety Device. An interlocking safety device is any means for the protection of workmen against accidents due to the operation of machinery, which is so arranged that it is made mechanically impossible for the operator to set a machine in motion while his hand or fingers, or other parts of his body, are in a dangerous position. In a press for example, it may be necessary to grip two levers, one with each hand, in order to throw the clutch and make the machine operate; in pneumatic devices, two valves may have to be opened, one with each hand; in electric operation, the pressure of two buttons to complete the circuit may be required.

Intermittent Gearing. Intermittent gearing is so designed that the driving gear imparts an intermittent motion to the driven gear, instead of driving it continuously. In many kinds of mechanism, this intermittent motion between a driving and a driven member is required. By using different forms of intermittent gears, the motion may be varied considerably. Some intermittent gearing is so arranged that each revolution of the driver moves the driven gear through part of a revolution, there being several periods of rest for the driven member before it is turned completely around or through one revolution. With other forms of intermittent gearing, the driven gear has only one period of rest for each revolution of the driver; the arrangement may also be such that there are several variable rest periods. Gears of the intermittent type are made in many different designs which are modified to suit the conditions governing their operation, such as the necessity for accurately locking the driven member while idle, speed of rotation, and the inertia of the part connected to the driven gear.

Internal Combustion Engines. Gas and oil engines, generally grouped together under the name *internal combustion engines,* are machines for the transformation of heat into work. They differ from other types of heat engines in that the fuel is

burned within the cylinder or working chamber of the engine, and the products of combustion constitute the working fluid. Internal combustion engines may use a gas, an easily vaporizable liquid, such as gasoline, or a liquid which is difficult to vaporize, such as fuel oil. Engines using gas as fuel are termed *gas engines;* those using gasoline are termed *gasoline engines;* and those using heavy oils are termed *oil engines.* Since the working fluid of all these engines is a highly heated gas, they are all frequently termed "gas engines," instead of using the longer, but more correct, name of "internal combustion engines."

Four-stroke Cycle: During the first stroke of a four-stroke cycle engine, the inlet valve remains open, and the exhaust valve remains closed. The piston is drawn forward by the revolution of the crank, and an intimate mixture of air and fuel or "charge" is drawn into the cylinder; hence, the first stroke of the cycle is called the *suction stroke.* At the end of the suction stroke, the inlet valve closes. As the crank continues to revolve, the piston is pushed back, and since both the inlet and exhaust valves are closed, the charge is compressed into the clearance space. Accordingly, the second stroke of the cycle is called the *compression stroke.* During this stroke, not only does the volume of the charge diminish and its pressure increase, but its temperature also increases, since the temperature of a gas always rises when it is compressed, unless special means are taken during the compression to cool the gas, and so remove the heat which is created in it by the work of compression.

While the engine is on or near the dead-center at the end of the compression stroke, the charge is ignited by an electric spark. The fuel is instantly burned, and a considerable quantity of heat generated. As a result the temperature of the charge is instantly raised, until it reaches a value of between 3000 and 4000 degrees F. This rise in temperature produces a corresponding rise in pressure, which is termed the *explosion.* Immediately after the ignition, the pressure of the charge reaches a value of from 250 to 700 pounds per square inch. After the explosion, the crank continuing to revolve, the piston again moves forward, both valves remaining closed. This is the power producing stroke. The charge expands in volume, forcing the piston forward. In consequence, this stroke of the cycle is called the *expansion stroke.* The work done by the expanding charge upon the piston is largely expended in accelerating the flywheel, which acts as a reservoir of energy. At the end of the expansion stroke, the exhaust valve opens, and the pressure of the charge falls to that of the atmosphere. The revolving crank forces the piston back, and the burned charge is expelled from the cylinder, during the fourth stroke, termed the *exhaust stroke,* and the cycle is complete. It will be noted

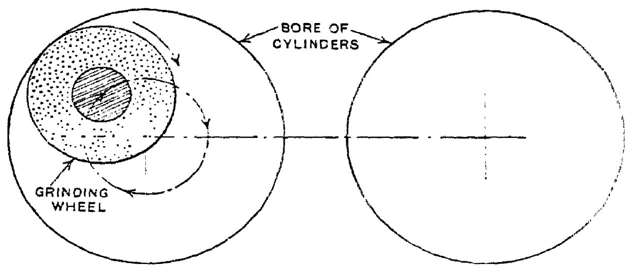
that the cycle requires four strokes or two full revolutions of the crankshaft.

Two-stroke Cycle: In a two-stroke cycle engine the piston acts as both an inlet and exhaust valve. Assume that the cylinder is filled with a mixture of air and fuel. The crank revolves, the piston rises, and the charge is compressed. When the piston is at or near its highest point, the charge is ignited, and the piston descends. During its upward stroke, the piston draws into the crankcase (which is an air-tight casting containing the crank and connecting-rod) a fresh quantity of charge, through the check-valve. During its downward stroke, the piston compresses this charge. When the piston approaches the bottom of its stroke, its motion uncovers an exhaust port, so that the burned charge escapes, and the pressure falls. An instant later the motion uncovers an inlet port, and the fresh charge forces its way in from the crankcase, driving the remainder of the burned charge before it. A projection on the top of the piston is for the purpose of deflecting the fresh charge, and preventing it from passing directly across the cylinder, and out at the exhaust. Engines of this type, using gasoline for fuel, are frequently employed for marine and stationary service whereas the four-stroke cycle engines are used on motor cars, airplanes, and for various other purposes.

Internal Expanding Clutch. This is a friction clutch provided with shoes which are forced outward against an enclosing drum by the action of levers connecting with a collar free to slide along the shaft. The engaging shoes are usually lined with wood.

Internal Gears. An internal spur gear has teeth formed on an interior surface instead of on an exterior one as in the case of an ordinary spur gear. Briefly, and perhaps somewhat unconventionally defined, it is an ordinary spur gear turned inside out. There are some advantages incident to the use of internal gears for particular applications, as compared with external gears of the same pitch and number of teeth. An internal gear has its teeth and those of its pinion protected to a very marked degree from inflicting or receiving injury, often making the use of a gear guard unnecessary, if the parts are properly designed in this respect. Owing to the fact that the cylindrical pitch surfaces in internal gearing have their curvature in the same direction, the teeth of the pinion approach and mesh with those of its mate somewhat more gradually and easily than when they are meshing with an external gear. This tends toward smoothness and quietness in running, as well as giving a slightly longer contact for each tooth. Internal gears of the same pitch and number of teeth have a much smaller center distance than external gears, which is often an advantage.

Cutting Methods: Internal spur gears are usually cut by one of the following methods: (1) By using a formed cutter and milling the teeth; (2) by a molding-generating process, as when using a Fellows gear shaper; (3) by planing, using a machine of the templet or form-copying type (especially applicable to gears of large pitch); and (4) by using a formed tool which reproduces its shape and is given a planing action either on a slotting or a planing type of machine. The machines used ordinarily for cutting internal gears are designs intended primarily for external gears. These machines may be arranged for internal gear-cutting by using some form of attachment which provides means of holding the cutter in the position required for forming gear teeth around an inner surface.



Action of Planetary or Eccentric-head Type of Cylinder Grinder

Internal Bevel Gear: The pinion cone of an internal bevel gear rolls on the interior surface of a concave gear cone, while in the more common type of bevel gearing, the pinion cone rolls upon the exterior surface of a convex gear cone; hence, the pitch cone angle of an internal gear is greater than 90 degrees.

Internal Gears, Williams. In the Williams system, the profiles of the internal gear teeth are straight lines, so that the tooth spaces are similar to those of an involute rack, while the teeth of the mating pinion have curved profiles of conjugate form. This gearing is designed to secure a much longer arc of tooth contact, improved operating action, reduced wear, and increased strength of the pinion teeth.

Internal Grinding Machines. On one type of internal grinding machine the work head is stationary and the wheel-spindle is traversed. The wheel-spindle of another type is supported by a stationary portion of the frame, and the work head is mounted on the table of the machine and travels to and from the grinding

wheel. The former type is used to a large extent in machines especially designed for internal grinding. Some machines, instead of being designed for internal grinding exclusively, are combination types which will grind both internal and external diameters on the work at the same chucking. In the design of internal grinders much attention has been given to the spindle and its mounting in order to obtain the high-speeds essential to efficient grinding.

For grinding cylinders, a special type of internal grinding machine has been developed in which the work does not have to be rotated, as is the case with the ordinary type of internal grinding machines. The grinding wheel not only rotates about its own axis but has a circular or planetary movement (as indicated by the diagram) so that it follows around the walls of the hole being ground as the work is fed in a lengthwise direction.

Internally-Fired Furnaces. The heating chamber and the combustion chamber of some furnaces are combined. This arrangement is applicable to forge furnaces, rod and rivet heaters, etc., in which an intense heat is required, and the work will not be seriously affected by the direct action of the flame. Melting furnaces of some types are also internally fired. It is but rarely desirable to have the flame proper strike directly against the cold work, as combustion is thereby retarded and soot is often deposited on the work, particularly when oil fuel is used. This type is largely confined to the use of gas and oil fuel. The common pit type of crucible melting furnace, using coke or hard coal, is a notable exception.

Internal Stresses. Castings are sometimes sprung out of shape by the internal stresses existing in the casting itself. These stresses are caused by the unequal cooling of the casting in the foundry. When a casting is made, the molten metal which comes in contact with the walls of the mold naturally cools first and, in cooling, contracts and becomes solid while the interior is still more or less molten. The result is that when the interior cools and contracts, the tendency is to distort the part which solidified first, and internal stresses are left in the casting.

International Atomic Weights. These are atomic weights which are based upon the value of the atomic weight of oxygen as 16.

International Electrical Units. A great deal of confusion occurred in the early days of electrical development because of the many changes in electrical standards. These standards were an attempt to define certain basic electrical units in terms of mechanical quantities. One of the early difficulties was the lack of accurate means of measurement; and as this accuracy was im-

proved, changes to correct errors in previous standards were made necessary. A series of International Congresses, meeting during the period from 1881 to 1908, worked toward the establishment of international electrical standards, and finally agreement was reached by a specially appointed International Commission which met in London in 1908. Based on this agreement, the ohm was defined from physical measurements as the first primary standard, the ampere was defined from physical measurements as the second primary standard, and the volt was established as a derived unit based on the ohm and the ampere.

The international ohm was defined as the resistance at zero degrees Centigrade of a column of mercury of uniform cross-section having a length of 106.300 centimeters and a mass of 14.4521 grams.

The international ampere was defined as the current which will deposit silver at the rate of 0.00111800 gram per second.

The international volt is a voltage that will produce a current of one international ampere through a resistance of one international ohm.

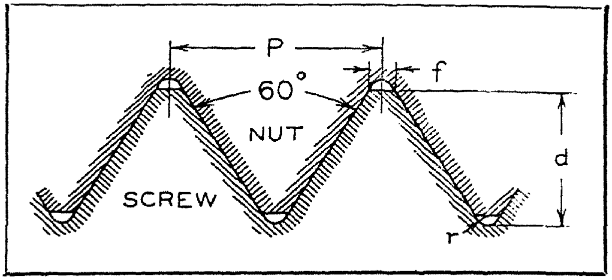
Some international units differ very slightly from the so-called "theoretical" practical units which are based upon the assumption of a fictitious magnetic quantity similar to the electric quantity or charge. Thus, experimental results show that the international ohm equals 1.0005 "theoretical" ohms.

These international units have, however, been discarded; and for standard measurements, the definitions of the theoretical (absolute) units, as internationally accepted, are now recommended for use. These theoretical units are not, in themselves, based upon primary standards kept in certain laboratories, but are derived from significant experimental laws.

International Metric Thread System. The Systeme Internationale Thread was adopted at the Internationale Congress for the standardization of screw threads held in Zurich in 1898. The thread form is similar to the American standard (formerly U. S. Standard), excepting the depth which is greater. There is a clearance between the root and mating crest fixed at a maximum of 1/16 the height of the fundamental triangle or 0.054 $\times$ pitch. A rounded root profile is recommended. The angle in the plane of the axis is 60 degrees and the crest has a flat like the American standard equal to 0.125 $\times$ pitch. This system has been adopted as standard by the International Standards Association, by most European countries using the metric system and by Japan. The original specification has been modified by the general adoption of a uniform pitch of 6 millimeters for the 72-, 76- and 80-millimeter sizes. The range of nominal diameters has also been extended beyond the original 80-millimeter maximum to 84

and then by increases of 5 millimeters with a constant pitch of 6 millimeters. Thread depth $d = 0.7035\ P$ max. and $0.6855\ P$ min. Radius r at root $= 0.0633\ P$ max. and $0.054\ P$ min.

The German metric thread form is like the International Standard but the thread depth $= 0.6945\ P$. The root radius is the same as the maximum for the International Standard or $0.0633\ P$.



International Metric Thread

International Metric Fine Thread: The form of thread is the same as the International system but the pitch for a given diameter is smaller. The metric fine thread is used on the European continent, although there is not as yet complete uniformity.

Interpolation. In mathematics, interpolation is the process of finding a value in a table or in a mathematical expression which falls between two given tabulated or known values. In engineering handbooks, the values of trigonometric functions are usually given to degrees and minutes; hence, if the given angle is to degrees, minutes and seconds, the value of the function is determined from the nearest given values, by interpolation.

Interpolation to Find Functions of an Angle: Assume that the sine of 14° 22′ 26″ is to be determined. It is evident that this value lies between the sine of 14° 22′ and the sine of 14° 23′. Sine 14° 23′ = 0.24841 and sine 14° 22′ = 0.24813. The difference = 0.24841 — 0.24813 = 0.00028. Consider this difference as a whole number (28) and multiply it by a fraction having as its numerator the number of seconds (26) in the given angle, and as its denominator 60 (number of seconds in one minute). Thus $26/60 \times 28 = 12$ nearly; hence, by adding 0.00012 to sine of 14° 22′ we find that sine 14° 22′ 26″ = 0.24813 + 0.00012 = 0.24825. The correction value (represented in this example by 0.00012) is *added* to the function of the *smaller* angle nearest the given angle in dealing with *sines* or *tangents* but this correction value is *subtracted* in dealing with cosines or cotangents.

Interpolation to Find Angle: Example: Find the angle whose cosine is 0.27052. A table of trigonometric functions shows that the desired angle is between 74° 18′ and 74° 19′ because the cosines of these angles are, respectively, 0.27060 and 0.27032. The difference = 0.27060 — 0.27032 = 0.00028. From the cosine of the *smaller* angle or 0.27060, subtract the given cosine; thus 0.27060 — 0.27052 = 0.00008; hence, $8/28 \times 60 = 17''$ or the

number of seconds to add to the smaller angle to obtain the required angle. Thus the angle whose cosine is 0.27052 = 74° 18′ 17″. Angles corresponding to given sines, tangents, or cotangents may be determined by the same method.

Invar. Invar is a nickel steel containing about 36 per cent nickel, together with about 0.5 per cent each of carbon and manganese, with metallurgically negligible quantities of sulphur, phosphorus, and other elements, the remainder being iron. It is made either in the open-hearth furnace or by the crucible method. It melts at about 1425 degrees C. (about 2600 degrees F.). The value of this alloy lies in the fact that it has a very small coefficient of expansion due to heat, and it is, therefore, used in scientific instruments, for standard length measurements, and in high-grade measuring tapes.

Invention, What Constitutes. See Patents.

Inventors, Joint. See Joint Inventors.

Inverted Synchronous Converter. This is a rotating electrical machine used for converting direct current into alternating current; see Synchronous Converter.

Inverted Type Accumulator. A hydraulic accumulator in which the cylinder, fitting over the plunger from above, supports the weights necessary to produce the required pressure, is known as an inverted type accumulator.

Involute. If a circular disk were placed upon a drawing-board, an involute curve would be described by the end of a taut line if the latter were unwound from this disk, in the plane of the board. The disk represents, in gear design, what is known as the *base circle,* because it is from this circle that the involute tooth curves are derived.

Involute Function. Involute functions are used in involute trigonometry or in certain formulas for solving problems relating to involute curves, as in the case of involute gearing. For example, involute functions are used in the basic formulas for checking the sizes of involute gears, either by measurement over pins or by the chordal measurement over two or more teeth. Involute function = tangent of angle — angle in radians.

For example, find the involute function of 19.09 degrees:

Tangent = 0.34608560. 19.09 degrees is equivalent to 0.33318335 radians.

0.34608560 — 0.33318335 = 0.01290225 which is the involute function.

Involute Gear Teeth. The involute curve is made use of in forming the teeth of the involute system of gearing, which is the system used for practically all cut-gear teeth. The involute gear-tooth system has the advantage over the cycloidal tooth system in that gears with involute teeth will run correctly even if the distance between the centers of the gears is not theoretically correct. The relative velocities of two gears having involute teeth will be the same even if their center distance is altered. The unmodified involute rack tooth has straight sides, but in practice the points may be slightly rounded off to avoid interference. The basic rack of the American Standard 14½ Degree Composite System has cycloidal curves above and below a straight mid-section. See Gear Tooth Standardization.

Involute Measuring Machine. The design of the Fellows involute measuring for checking gear tooth profiles is based on the fact that all involutes developed from the same base circle are alike. A single master cam is used for checking the teeth of any size gear within the capacity of the machine. The master cam takes the place of the "base roll" employed in previous machines, which required a different size roll for each size or diameter of gear tested.

The master involute cam is developed from a base circle having a radius greater than that of the largest size gear accommodated by the machine. Thus, any gear having a smaller base-circle radius than the master cam can be checked by simply changing the position or radial distance of the pointer from the axis of the gear. The rate of travel of the slide that carries the indicator is changed automatically to agree with the base-circle setting.

The pointer that checks the involute is automatically set to the required base-circle radius by locating the main slide in the correct position by means of standard size-blocks. A size-block is also employed for setting the pointer in the correct "radial" or "starting" position.

In cases where it is necessary to measure a modified form of involute, a graduated dial is employed which moves with the work, and, in conjunction with the dial indicator, measures the exact amount that the involute is modified and the angle through which the profile is modified. This device can also be employed for determining the height of the fillet and for checking the flanks of gear-shaper cutters. The machine can also be used to determine the base-circle diameter of a gear.

Iodine Number. Iodine value or number is the number of milligrams of iodine that one gram of a fat or oil will absorb under specific conditions, and for fixed oils the iodine value is usually fairly constant, marked variation indicating adulteration.

Ion. An ion is an electrified portion of matter of sub-atomic, atomic, or molecular dimensions. An *anion* is an ion that is negatively charged. A *cation* is an ion that is positively charged.

Ionization. When certain substances, such as salts of various kinds, are dissolved in water, they tend to break up or dissociate into an equal number of negatively charged and positively charged elements or particles. These elements or particles are called *ions* and are supposed to be atoms or groups of atoms which have gained or lost a certain number of electrons, thus giving them a positive or negative charge. The solution is said to be ionized; and when it is used to conduct an electric current, it is called an *electrolyte*.

Iridio-Platinum. Iridio-platinum is an alloy of iridium and platinum, containing about 10 per cent of iridium and 90 per cent of platinum. The alloy is used for international weight standards, electrodes exposed to acid liquids, and wires forming part of high-temperature pyrometers. It is a remarkably hard alloy, susceptible of high polish. Very few chemical reagents attack it.

Iridium. Iridium is one of the metallic chemical elements of the platinum group, its symbol being Ir, and its atomic weight, 193.1. It is a metal of silvery-white color and is always present in platinum ores in the form of alloys of platinum and iridium and of osmium and iridium. It is a brittle, hard metal and is one of the heaviest substances known, its specific gravity being 22.42, which is equivalent to a weight per cubic inch of 0.809 pound. Iridium is fusible only with great difficulty, its melting point being at 2300 degrees C. (about 4170 degrees F.). Practically all commercial platinum contains iridium. It is used for the points of gold pens in fountain-pen manufacture, and is also alloyed with platinum to act as a hardener for this metal. Very little pure platinum is now being used, nearly all the commercial metal passing under this name being so-called "hard platinum," which is an alloy of platinum and iridium.

Iridosmium. Iridosmium is an alloy of the metals iridium and osmium, which is found in nature in different proportions. The alloy has a specific gravity varying from 19.3 to 21, and a hardness almost equal to that of quartz. The color resembles that of tin or steel. The alloy usually contains small percentages of rhodium, ruthenium, and platinum. It is found in connection with platinum ores in the Ural Mountains and in Northern California.

Iron. The term "iron," as used in the chemical or scientific sense of the word, refers to the chemical element iron or pure iron, which is the chief constituent in all commercial iron and steel. As applied to the commercial product, however, the term

"iron" is most generally used to indicate wrought iron, as distinguished from steel or cast iron. Pure iron is not used in the industries, but all the commercial products containing iron as the chief element—wrought iron, cast iron, steel castings, Bessemer steel, open-hearth steel, crucible steel, alloy steel, etc.,—contain also small percentages of carbon and a number of other elements, the presence of which determine the characteristics of each class of commercial iron and steel. Iron is found in nature in the form of iron ore, and all the irons and steels used in the industries are produced from iron ore by a number of different processes.

Pure iron is silvery white, tenacious, malleable, ductile, and has a high melting point. The chemical symbol of iron is Fe, its atomic weight is 55.84, and its specific gravity, 7.84, giving a weight per cubic inch of 0.283 pound. Its linear expansion per unit length in degrees F. is 0.0000065, and its average specific heat for temperatures between 60 and 212 degrees F., 0.11; this value of the specific heat increases with the temperature, up to about 1550 degrees F., and then diminishes. The melting point of pure iron is given by the Bureau of Standards as 1520 degrees C. (2768 degrees F.).

Iron, Acid-Resisting. See Duriron.

Iron and Steel Definitions. The International Association for Testing Materials adopted the following definitions of the most important forms of iron and steel:

Alloy Cast Irons: Irons which owe their properties chiefly to the presence of an element other than carbon.

Alloy Steels: Steels which owe their properties chiefly to the presence of an element other than carbon.

Basic Pig Iron: Pig iron containing so little silicon and sulphur that it is suited for easy conversion into steel by the basic open-hearth process (restricted to pig iron containing not more than 1.00 per cent of silicon).

Bessemer Pig Iron: Iron which contains so little phosphorus and sulphur that it can be used for conversion into steel by the original or acid Bessemer process (restricted to pig iron containing not more than 0.10 per cent of phosphorus).

Bessemer Steel: Steel made by the Bessemer process, irrespective of carbon content.

Cast Iron: Iron containing so much carbon or its equivalent that it is not malleable at any temperature. The committee recommends drawing the line between cast iron and steel at 2.20 per cent carbon.

Cast Steel: The same as crucible steel; obsolete, and confusing; the terms "crucible steel" or "tool steel" are to be preferred.

Crucible Steel: Steel made by the crucible process, irrespective of its carbon content.

Gray Pig Iron and Gray Cast Iron: Pig iron and cast iron in the fracture of which the iron itself is nearly or quite concealed by graphite, so that the fracture has the gray color of graphite.

Malleable Castings: Castings made from iron which when first made is in the condition of cast iron, and is made malleable by subsequent treatment without fusion.

Malleable Iron: The same as wrought iron.

Malleable Pig Iron: An American trade name for the pig iron suitable for converting into malleable castings through the process of melting, treating when molten, casting in a brittle state, and then making malleable without remelting.

Open-hearth Steel: Steel made by open-hearth process irrespective of its carbon content.

Pig Iron: Cast iron which has been cast into pigs direct from the blast furnace.

Puddled Iron: Wrought iron made by the puddling process.

Refined Cast Iron: Cast iron which has had most of its silicon removed in the refinery furnace, but still contains so much carbon as to be distinctly cast iron.

Steel: Iron which is malleable at least in some one range of temperature and, in addition, is either (*a*) cast into an initially malleable mass; or, (*b*) is capable of hardening greatly by sudden cooling; or, (*c*) is both so cast and so capable of hardening.

Steel Castings: Unforged and unrolled castings made of Bessemer, open-hearth, crucible, or any other steel.

Washed Metal: Cast iron from which most of the silicon and phosphor have been removed by the Bell-Krupp process without removing much of the carbon, still contains enough carbon to be cast iron.

Weld Iron: The same as wrought iron; obsolete and needless.

White Pig Iron and White Cast Iron: Pig iron and cast iron in the fracture of which little or no graphite is visible, so that their fracture is silvery and white.

Wrought Iron: Slag-bearing, malleable iron, which does not harden materially when suddenly cooled.

Iron Founding in America. Joseph Jenks, who came from England to Lynn, Mass., about 1642, is said to have been the first founder who worked in brass and iron on the Western continent. An iron quart pot is said to have been the first casting made. The iron foundry and forge was located near a bog-iron mine and had the backing of Gov. Winthrop. From this crude beginning the spread of iron manufacturing continued without a break up to the present time. Jenks built for the town of Boston, the first fire engine used in the United States, and also constructed machines for drawing wire.

Iron in Iron Ore. Iron ore contains ordinarily from 35 to 65 per cent of iron, and, in addition, oxygen, phosphorus, sulphur, silica (sand), and other impurities. If the ore contains less than 40 per cent of iron, it must first be concentrated, and, if less than 25 per cent of iron, it is not considered a commercial product, owing to the excessive cost of smelting. The ores mined in the United States average slightly over 50 per cent of iron, although the "Lake" ores sometimes contain over 60 per cent. Iron ores which consist of carbonates—minerals in which iron is present with oxygen and carbon—and sulphides—minerals in which the iron is present with sulphur—are also used, but these ores must be roasted to drive off the carbonic acid of the carbonate ore and reduce the sulphur in the sulphide ore. Iron ore in which sulphur is present to an amount exceeding 1 per cent must always be treated in this manner. Magnetite is an ore that has derived its name from the fact that it is attracted by the magnet. In magnetite ores, iron is present as a magnetic oxide, Fe_3O_4, which, when pure, contains 72.4 per cent of iron. See also Magnetite, and Hematite.

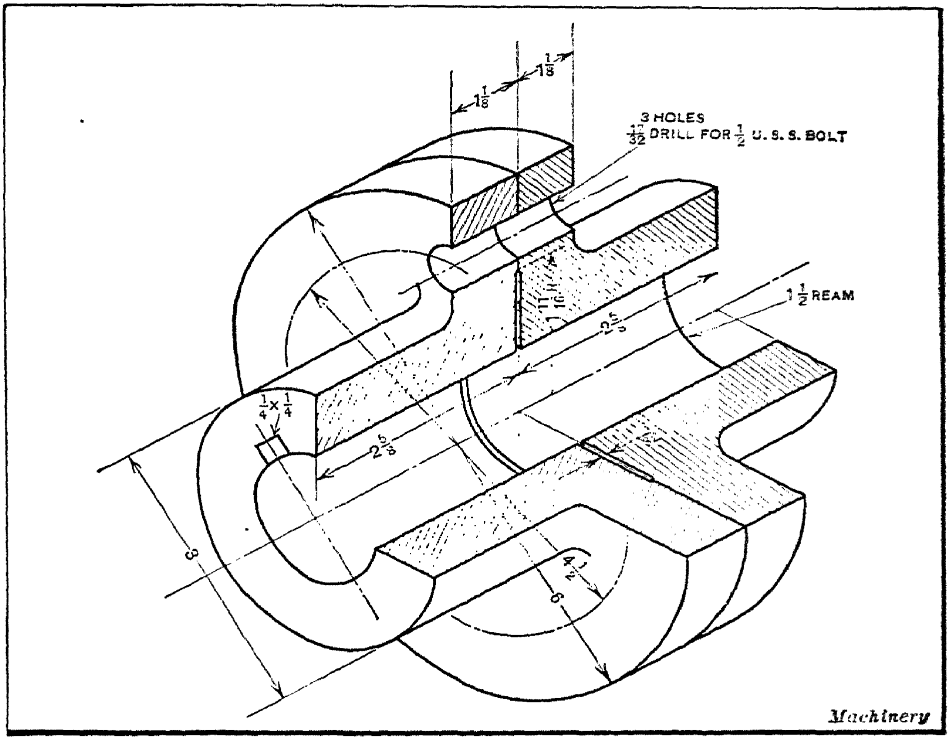
Iron Ore Grading. Iron ore is graded according to the percentage of phosphorus it contains. A low percentage of phosphorus—under 4½ per cent—makes it available for the Bessemer steel-making process, and such ore is called Bessemer ore. The non-Bessemer ore, which contains a higher percentage of phosphorus, is made into steel by the basic open-hearth process, which admits of the elimination of the phosphorus.

Isinglass. This is a term commonly confused with mica, although it designates a totally different substance. The material is used in belt cements of the best grade. It is prepared from the air bladders of the Russian sturgeon, caught in the Baltic Sea. The isinglass from the Russian sturgeon is superior to that made from the American sturgeon.

Isolantite. Isolantite is the name of a material that is claimed to be harder than glass, but not brittle, having a toughness greater than cast iron, that it is capable of resisting incandescent heat followed by a plunge in cold water without damage, that it is practically moisture-proof, and that it can be produced in a soft state so that it can be machined into all kinds of shapes and sizes with great precision, and can have threads cut on it, after which it can be hardened to obtain the extreme properties mentioned. It is unaffected by commercial acids, alkalis, and solvents, and makes an effective electrical insulator. When in its soft state, it is turned, drilled, milled or threaded in the same manner as metal. The threads are said to be even stronger than metal threads, and machine screws screwed into

threaded "Isolantite" are said to have been stripped of their threads before the threads in the "Isolantite" gave way. The material is pure white and smooth in its finished state.

Isometric Projection. In ordinary mechanical drawing, the orthographic method of projection is used, the object being represented in two or more views in which all lines are drawn to the



Isometric Drawing of a Shaft Coupling

same scale. Another system of representing objects, known as "isometric projection" is used to show in one view the appearance and the dimensions of an object in all directions; that is, to show both length or height, breadth or width, and thickness. The isometric method of projection differs from perspective drawing in that it shows the object in its true dimensions, all lines in any given direction being drawn to some given scale, and all lines that are parallel in the object being shown parallel in the drawing. The perspective drawing, on the other hand, shows the object as it would appear to the eye, the lines converging toward a common vanishing point. The illustration shows an isometric drawing of a shaft coupling, partly in section. Note that the

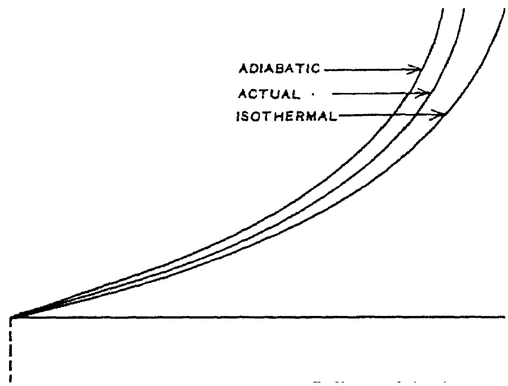


Fig. 1. Adiabatic, Actual, and Isothermal Curves of Compression

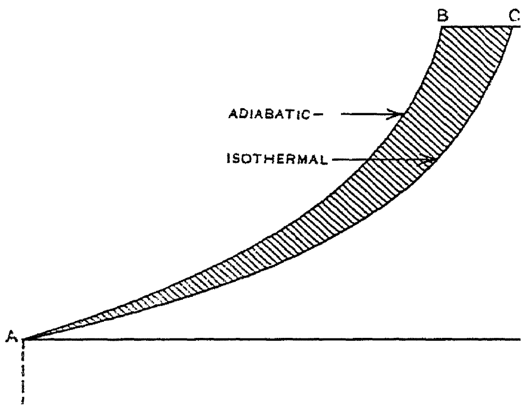


Fig. 2. Additional Work Required for Adiabatic over Isothermal Compression

hub thickness, for example, is the same at each end of the drawing.

Isothermal Expansion and Compression. When a given volume of gas expands, the temperature naturally decreases, assuming that heat is not supplied to compensate for the loss due to expansion. If the expanding gas has enough heat added to it to keep the temperature constant, the expansion is isothermal and a curve representing such expansion is sometimes called the expansion curve of constant temperature.

When air is compressed, heat is generated and the temperature rises. If this heat could be removed as fast as generated, so as to maintain a constant temperature during the process of compression, *isothermal* compression would be obtained. If it were possible to compress air without adding to or removing the heat generated by the process of compression, *adiabatic* compression would be obtained. In the actual compression of air under practical working conditions, neither of these results is obtained, the curve of compression lying between the two, somewhat as shown by the diagram. The isothermal curve is only approached in the case of slow-speed machines where the air is in contact with the water jackets for a longer period than usual. In the ordinary type of compressor, working under normal conditions, the curve lies nearer to the adiabatic, as indicated by the upper illustration, Fig. 1, and for this reason practical computations in connection with the design of compressors are usually based on adiabatic compression. The power requirements, however, are greater for adiabatic than for isothermal compression, due to the higher temperature of the air and the increased volume for a given pressure. This is shown graphically by the lower diagram, Fig. 2, the area *ABDE* representing the work required to compress and discharge a given volume of air adiabatically, and *ACDE*, the work required to compress and discharge the same volume of air to the same pressure isothermally. The shaded portion *ABC* represents the saving in power which might be made, were it possible to secure isothermal compression under practical working conditions. The energy represented by this area is wasted, so far as useful work is concerned, because, being in the form of heat, it is all lost by radiation before the air is used. Furthermore, the excessive temperature of the air at high pressures vaporizes the lubricating oil in the cylinder, thus forming an explosive mixture which may become ignited and cause serious damage.

J

Jacks. Lifting jacks are made in many different types and sizes, ranging from the small jacks used for leveling and supporting work on planers to the powerful hydraulic jacks capable of lifting a locomotive or even greater weights. The mechanism by means of which jacks are operated also varies greatly. One of the simplest types consists of a screw which is inserted in a suitable base. There are also the gear-and-rack and the lever-and-rack types, in addition to many different designs that are hydraulically operated. While the lifting capacity varies greatly, in general, screw-jacks and those belonging to the reduction gear-and-rack class are capable of lifting loads up to about twenty tons, whereas those operated by hydraulic power ordinarily vary in capacity from four or five tons up to about five hundred tons.

Jacks, Hydraulic. See Hydraulic Jacks.

Jacoby Metal. Jacoby metal is a tin-antimony-copper alloy having a composition similar to britannia metal. It is suitable to be used for plated ware. The composition is as follows: Tin, 85 per cent; antimony, 10 per cent; and copper, 5 per cent. It can also be used as a high-grade bearing metal.

Jal-Ten. Open-hearth manganese copper-bearing steel with high resistance to weather corrosion. Minimum tensile strength, 80,000 pounds per square inch; minimum yield point, 50,000 pounds per square inch; minimum elongation in 2 inches, 20 per cent; minimum Brinell hardness, 160. Three times greater resistance to atmospheric corrosion than ordinary open-hearth steel. Specifically suitable for railway car construction and for all purposes where high strength, resistance to abrasion, and resistance to all types of corrosion such as would be met with in railway service are required.

Jamb Coke. Jamb coke also known as "soft coke" and "heating coke," is the coke that is obtained next to the back and front of the coke oven and around the oven doors when producing regular foundry and furnace coke.

Jam-Nut. A jam-nut is a secondary nut which is used in conjunction with the regular holding nut on a bolt, the object of the jam-nut being to keep the other nut from working loose, due to vibrations. Jam-nuts are also known as *check-nuts* or *lock-nuts*. It is preferable to put the jam-nut below the regular nut instead of above it, as is often done by mechanics. The jam-nut

ordinarily is made about five-eighths the thickness of the regular nut. The regular nut thickness is about seven-eighths of the diameter of the bolt. The reason why the thinner jam-nuts should be placed below and the thicker regular nuts on top is that the pressure on the threads of the lower nut is small compared with the pressure on the threads of the upper nut, if the nuts are tightened in such a manner that they actually bind each other in place. The upper nut must be tightened down so as to place a greater stress on the bolt than is placed on it by the lower nut, because in order to secure a locking action the nuts must bear against opposite sides in the thread. If the upper nut is not tightened down so as to place such a stress on the bolt that the nuts bear on opposite sides of the thread, then the check-nut does not act as a check-nut at all, but merely increases the length of the nut already in place. This may have some tendency to prevent the nut from jarring loose, but it is not the condition actually sought.

Japanese Alloys. Metal alloys used for Japanese art work are composed mainly of copper with a number of other metals. One analysis shows 94-5 per cent of copper; 3.7 per cent of gold; 1.5 per cent of silver; 0.1 per cent of lead; with small percentages of zinc and iron. Another alloy is composed of 67.3 per cent copper; 32 per cent of silver; and 0.5 per cent of lead; with small percentages of gold, zinc, and iron. Another easily fusible metal for casting in plaster-of-paris is composed of 91.4 per cent of copper; 5.7 per cent of tin; and 2.9 per cent of lead. The term "Japanese alloy," therefore, does not signify any one composition.

Japanning. Japanning is a process that consists of applying an opaque, usually black, varnish to the surface of the object to be japanned, and baking it on the surface by means of high temperature in a japanning oven. The art of japanning originated with the Japanese; hence, the name. The Japanese made their varnish or liquor from the secretions of certain kinds of trees. These, upon being exposed to the air, assumed a deep, dark color, to which pulverized charcoal was then added. The varnish so made was applied to the surface of the object to be coated in several successive coats. Each coat of varnish was baked on the surface in the sun before the next coat was applied. After the final coat had been baked on, it was polished, thus producing a smooth, glossy surface. The modern methods of japanning are different in everything, except the principle, from the methods used by the Japanese. The japan varnish used at the present time in manufacturing processes is composed generally of asphaltum, gum, linseed oil, turpentine, benzine, and some coloring matter, such as charcoal or boneblack. Objects may be coated with japan to protect them or for decorative purposes.

Jarno Taper. The Jarno taper was originally proposed by Oscar J. Beale of the Brown & Sharpe Mfg. Co., Providence, R. I. No table is necessary for the Jarno taper socket, as this socket is based on such simple formulas that practically no calculations are required when the number of taper is known. The taper per foot of all Jarno taper sizes is 0.600 inch on the diameter. The diameter at the large end is as many eighths, the diameter at the small end is as many tenths, and the length as many half inches as are indicated by the number of the taper. For example, a No. 7 Jarno taper is $\frac{7}{8}$ inch in diameter at the large end; 7/10, or 0.700 inch at the small end; and 7/2, or $3\frac{1}{2}$ inches long. The Jarno taper is used on various machine tools, especially profiling machines and die-sinking machines.

Jet Condenser. The jet condenser condenses the exhaust steam of a steam engine or turbine by mixing the condensing or cooling water directly with the steam. In one type the exhaust steam enters at the top of the condenser, meeting the injection or cooling water, which is drawn in by suction due to the partial vacuum, and is discharged in the form of a spray, resulting in complete condensation of the steam. A greater drop in pressure for a given amount of cooling water is obtained in a jet condenser than in a surface condenser.

Jewelers' Borax. Jewelers' borax, also known as octahedral borax, is a form of borax suitable for use as a flux in soldering or welding.

Jib Crane. A jib crane consists of a post or pillar supported and pivoted at top and bottom, from which a horizontal arm or jib extends. The jib has a crab or trolley moving in a radial direction along it. Generally, the jib is supported by a strut placed in an inclined direction between the vertical post and the jib.

Jig-Boring Machine. The jig-boring machine is designed expressly for jig boring or similar work and is so arranged that either the part to be bored, or the boring spindle or spindles (or both work and spindles) can be adjusted to accurately locate the holes at given center-to-center distances without preliminary measurements or laying out. One design of jig-boring machine has a single spindle adjustable on a cross-rail located above a horizontal work-table, which may be adjusted along its bed in a direction at right angles to the cross-rail. With this machine, the work is located in the required position by moving the horizontal work-table lengthwise and the vertical spindle laterally along its cross-rail. Another type of jig-boring machine which is extensively used is so designed that adjustments for locating

various holes to be bored are obtained by lengthwise and lateral or cross-adjustments of a compound type of work-holding table.

Measuring Devices: Jig-boring machines are equipped with accurate means of measuring the longitudinal and lateral adjustments for boring various holes to given dimensions within close limits. Some machines have precision lead-screws with micrometer dials. Another type of measuring device consists of vernier scales which show the lengthwise and lateral measurements. A third method consists in using end-measuring rods and micrometers between adjustable stops. To obtain greater refinement and insure uniform measuring pressure for all measurements, contact at one end may be with a dial gage. Linear scales may be used in conjunction with the end-measuring micrometers, for approximate adjustments.

Jig Bushings, Standard. The American standard covers the different types of jig bushings in common use. This standard includes a range of bushing sizes and also the following types of bushings:

Renewable Bushings: Renewable wearing bushings to guide the tool are for use in liners which in turn are installed in the jig. They are used where the bushing will wear out or become obsolete before the jig or where several bushings are to be interchangeable in one hole.

Press Fit Bushings: Press fit wearing bushings to guide the tool are for installation directly in the jig without the use of a liner and are employed principally where the bushings are used for short production runs and will not require replacement. They are intended also for short center distances.

Liner Bushings: Liner bushings are provided with and without heads and are permanently installed in a jig to receive the renewable wearing bushings. They are sometimes called "master bushings."

Jig Plate Thickness: The American Standard lengths of jig bushings are based on standardized or uniform jig plate thicknesses of 5/16, $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{3}{8}$, and $1\frac{3}{4}$ inches.

Jig Grinder. This machine is similar in principle to a jig borer. It is designed primarily to correct the location of holes in hardened-steel parts, jigs, master plates, gage parts, etc. This grinder is especially applicable in making precision, compound, and progressive dies that frequently require holes to be spaced accurately within limits of 0.0005 inch or less.

Jigs and Fixtures. Jigs and fixtures serve the purpose of holding and properly locating a piece of work while it is being machined; they are provided with necessary appliances for guiding, supporting, setting, and gaging the tools in such a manner

that all the work produced in the same jig or fixture will be alike in all respects, even with the employment of unskilled labor. As a general rule, a jig is a special tool, which, while it holds the work, or is held onto the work, also contains guides for the respective tools to be used; whereas a fixture is only holding the work while the cutting tools are performing the operation on the piece, without containing any special arrangements for guiding these tools. The fixture, therefore, must, itself, be securely held or fixed to the machine on which the operation is performed; hence, the name. A fixture, however, may sometimes be provided with a number of gages and stops, although it does not contain any special devices for the guiding of the tools. The definition given, in a general way, would, therefore, classify jigs as special tools used particularly in drilling and boring operations, while fixtures, in particular, would be those special tools used on milling machines, and, in some cases, on planers, shapers, and slotting machines.

Jobbers' Reamer. This style of reamer is similar to a hand reamer, but it is provided with a taper shank so that it may be used for machine reaming. The shank is nearly always a Morse standard taper. Jobbers' reamers are fluted with the same kind of fluting cutters as reamers generally. The clearance is usually ground flat.

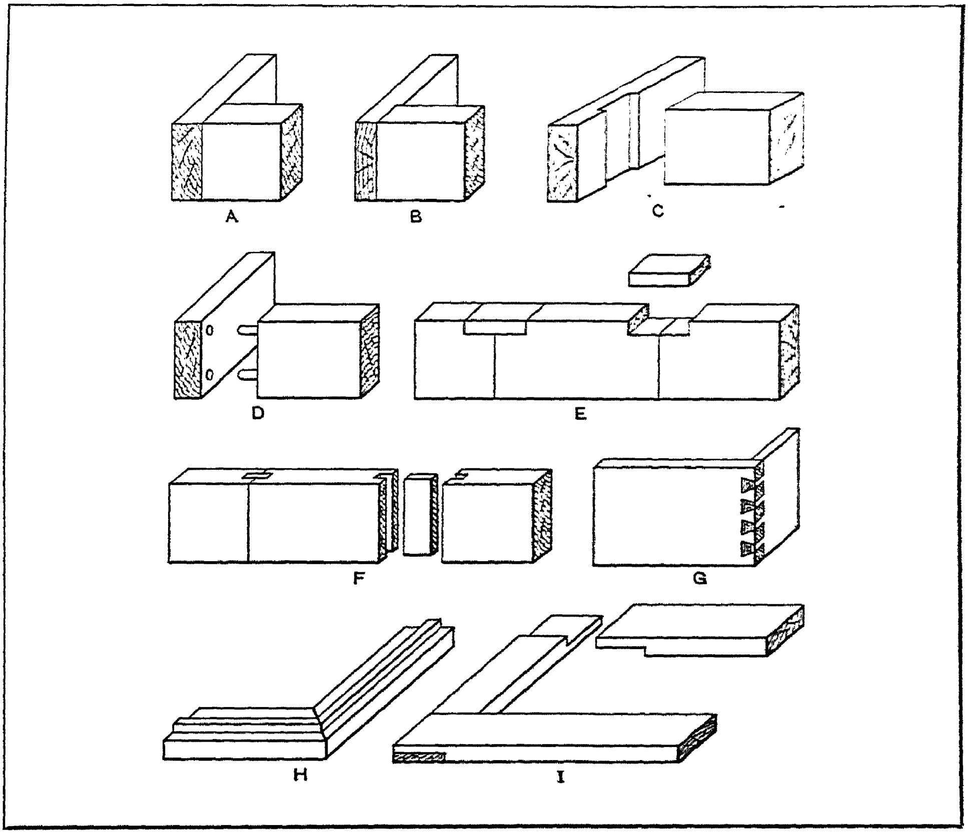
Jointer. The "hand jointer," which is sometimes referred to as a "buzz planer," is used in wood-working shops for jointing and edging stock, the material being pushed by hand across the circular cutters that revolve at a high rate of speed. When in good condition and skilfully used, a plane surface or a straight edge is very easily produced.

Joint Inventors. The term "joint inventors" is one that has been more or less misunderstood, not only by inventors, but also by others interested in patents. A person who furnishes capital only is in no sense a joint inventor, and his interest in the invention and the patent to be obtained therefor should be conveyed by an assignment executed in due form. To make clear the meaning of "joint inventors," suppose one inventor in collaboration with another, devises an engine for automobiles, both working on this particular part of the machine, and one making a suggestion here and the other there, a joint inventorship would exist. On the other hand, if one inventor were to design the motor, and his co-worker the transmission or the differential, there would not be a joint inventorship, for the reason that the motor could operate independently of the particular type of transmission employed, and the transmission could operate independently of the engine.

Joint Patents. Where two or more persons work to perfect an invention, the application must be filed jointly, and the patent is issued in their names. And where two men work to perfect an invention, neither can apply for a patent as sole inventor and obtain a valid patent. Furthermore, the law is well established that where a patent is issued jointly to two or more inventors, either has the right to sell his interest, or manufacture and sell the invention, or license others to do so, without permission from the other inventor.

Joints Used in Patternmaking. The different forms of joints commonly used in the construction of patterns and in many other kinds of wood-working, are shown by the diagrams.

Butted Joint: The butted joint *A* is the simplest form used in wood-working; two pieces are butted or placed one against the other and fastened with nails or screws, the latter giving a stronger joint.



Joints Used in Patternmaking

Rabbeted Joint: The rabbeted joint is used in place of the butted joint when greater strength is required. The end of one piece is cut back or rabbeted, as shown at *B*, to receive the "butt" of the second piece.

Dado Joint: The dado joint *C* is a standard for square and rectangular core-boxes. It prevents the ends from being rammed out or pushed in, and when it is fastened with screws, the box readily parts at the corners.

Doweled Joint: The doweled joint *D* is a butted joint strengthened by dowel-pins.

Reinforced Butted Joint: In making the reinforced butted joint *E*, a portion of each abutting section is cut away to receive a piece that covers the joint and prevents the sections from parting.

Splined or Feathered Joint: The pieces to be joined are grooved to receive a spline or feather (as shown at *F*) which strengthens the joint. This form is used for fastening the arms of wheels and pulleys where they join at the center, and also to secure the joints of rings or flanges that are built of a single course of segments.

Dovetailed Joint: This form of joint (which is shown at *G*) is used principally for holding the corners of beds and light boxes. The angle of the dovetails should be about 15½ degrees.

Mitered Joint: The mitered joint is used for connecting the corners of molding, etc. The angle for cutting is one-half the included angle of the connecting pieces. A 45-degree joint is shown at *H*.

Half-lapped Joint: This joint is used for constructing framework; one-half of each piece is cut away as shown at *I*, so that, when the two sections are fastened together, they will be flush at the joints.

Joule. The unit of work in electrical engineering, as recommended by the International Electrical Congress, in Chicago, 1893, and approved as a legal unit of electrical measure by an Act of Congress, July 12, 1894, is known as the *joule*, which is equal to the energy expended in one second by one ampere against the resistance of one ohm. One joule, expressed in mechanical equivalents, equals 0.7376 foot-pound, or 0.0000002778 kilowatt-hour. Commercially, this unit is too small and, therefore, either the watt-hour, which is 3600 times larger, or the kilowatt-hour, which is 3,600,000 times larger, is used.

Journal. A journal is that part of a shaft or axle which is supported by and revolves in a bearing.

K

Kahle's Cell. This is a primary cell or battery, known as a "standard" cell, used for obtaining a certain standard value of electromotive force under given conditions. In this cell, the positive electrode is amalgamated zinc, and the negative electrode, mercury. A paste of mercurous sulphate and zinc sulphate is placed upon the mercury and acts as a depolarizer. A saturated zinc sulphate solution acts as the electrolyte. The electromotive force of this cell is 1.43 volts at 15 degrees C. (59 degrees F.).

Karmarsch Metal. A bearing metal of the tin-antimony-copper alloy group, containing 70.8 per cent of tin, 19.7 per cent of antimony, and 9.5 per cent of copper is known as Karmarsch metal. Another metal, known by the same name and used for the same purpose, is composed of 71.4 per cent of tin, 7.2 per cent of antimony, and 21.4 per cent of copper.

Keep's Test. A method for testing the hardness of metals, which was introduced in 1887 by Keep, is known as "Keep's test." A standard steel drill is caused to make a definite number of revolutions while it is pressed with standard force against the metal specimen to be tested. The hardness is automatically recorded on a diagram on which a perfectly soft material gives a horizontal line and a material as hard as the drill itself, a vertical line. Intermediate degrees of hardness are represented by corresponding angles between 0 and 90 degrees.

Kelsanite. Non-inflammable liquid, which can be applied to metal parts by brushing, spraying, or dipping. Protects surface from corrosion or dirt, as it is both waterproof and air-tight. Coating has high adhesive qualities, but does not vulcanize to surfaces on which it is applied. After the coating has served its purpose, it can be stripped off like a cellophane wrapper. For the protection of parts or entire machines during storage or transportation; for protecting parts to be electroplated at points where the plating is not wanted; for "masking" portions of surfaces that are to be painted.

Kelvin's Law. Kelvin's law relates to the most economical size of conductors for transmitting electric power. It is as follows: The most economical area of a conductor is that for which the annual interest on the capital outlay equals the annual cost on the energy loss in the conductors.

Kem Bakolescent and Kem Plastite. An enamel applicable to plastic surfaces. Available in iridescent form (Kem Bakolescent) or in solid colors (Kem Plastite). Applied by either dipping or spraying. Useful in dressing up molded parts for vacuum cleaners, electrical wiring devices, radio cabinets, automobile parts, etc.

Kennametal. A tungsten-titanium-carbide compound having great wear and corrosion resistance and strength. In one instance, where it was previously necessary to change as many as seven valves in twenty-four hours, Kenametal-tipped valves and seats gave such service that only one valve had to be replaced every one or two weeks. Suitable for pump and other valves that are subject to unusual abrasive or corrosive action. Balls and seats of this material for oil-well pump valves have demonstrated their value in severe tests.

Kennedy Key. The Kennedy or double key system is used in rolling mills and is adapted to the transmission of heavy loads, especially where the torque is intermittent and the direction of rotation periodically reversed. Each key is so located that a diagonal line passing through two corners of the key approximately intersects the shaft axis. The keys have a taper of 1/8 inch per foot on the hub side and the sides fit closely between the shaft and hub. The keys are driven in from opposite sides of the hub.

Kerosene. A refined petroleum distillate having a flash point not below 73° F. (23° C.), as determined by the Abel Tester (which is approximately equivalent to 73° F. (23° C.) as determined by the Tag Closed Tester) and suitable for use as an illuminant when burned in a wick lamp. Note.—In the United States of America local ordinances or insurance regulations require flash points higher than 73° F. (23° C.), Tag Closed Tester.

Kerosene Lubrication. Kerosene has proved effective as a lubricant for the plain bearings of grinding wheel spindles. The following information is based upon the experience of the Norton Co. This type of lubrication is recommended only for plain bearings to which an ample flow of lubricant is delivered. It is not recommended for drip-lubricated bearings. The spindle journals of machines intended for kerosene lubrication are finished by methods that give them a highly reflective mirror-like surface. The surfaces thus finished are accurate in size and straightness to 0.0001 inch, and show readings from 1 to 2 micro-inches on the Profilometer.

While kerosene has been used for many years as a spindle lubricant in the high-speed internal spindles supplied with Norton tool and cutter grinders, a high-quality oil with a Saybolt viscosity

rating of from 60 to 185 at 100 degrees F. has previously been employed for the spindles of external grinders which operate at speeds ranging from about 800 to 1800 R.P.M., depending on the grinding wheel diameter. From 0.001 to 0.002 inch clearance for oil was provided in the bearings, and a bearing temperature of about 140 degrees F. was considered normal. With kerosene lubrication, these clearances can be safely reduced to approximately one-fifth of that formerly provided, and the temperature of the bearing will not rise much, if any, above 100 degrees F. The kerosene temperature does not rise above 100 degrees F. and with kerosene lubrication the fluctuations in temperature are very slight. Consequently, the repetitive expansion and contraction changes of the grinding wheel unit elements are greatly reduced.

Kewanee Union. The Kewanee pipe union has one pipe end of brass and the other of malleable iron, with a ring or nut of malleable iron. The arrangement and finish of the several parts is such as to provide a non-corrosive ball-and-socket joint at the junction of the pipe ends, and a non-corrosive connection between the ring and brass pipe end.

Key. A key of the type commonly used in machine construction consists ordinarily of a piece of steel, either square or rectangular in cross-section, which is inserted into a keyway or keyseat formed partly in a shaft and partly in the hub of a gear, pulley, or other part which, by means of the key, is driven positively and prevented from rotating relative to its shaft. While keys are used primarily to prevent relative rotation between shafts and such parts as pulleys, gears, etc., they also prevent axial movement in many cases, owing to the frictional resistance between the keyed parts. The type of key that may properly be employed in any case naturally depends somewhat upon the class of work for which it is intended.

The *sunk key* is the most common type. This is of rectangular section and engages a groove or slot formed both in the shaft and hub of the gear or pulley. The so-called *saddle key* does not enter a slot in the shaft, but is curved on the under side and is slightly tapered on top so that when driven into place the shaft is gripped by the frictional resistance. The *flat key* is a rectangular shape which bears upon a flat surface formed on one side of the shaft. The draw or *gib key* is a sunk key which has a head by means of which it can be removed. The *round tapered key* is simply a taper pin which is driven into a hole that is partly in the shaft and partly in the hub; this form is used for light work. The name *feather* or *spline* is applied to a key which is fixed to either a shaft or hub, as when a gear must be driven

by a shaft, but at the same time be free to slide in a lengthwise direction. The *Woodruff key* is a section of a disk, the part which enters the shaft being circular.

The width of an ordinary sunk key ordinarily is equal to about one-fourth of the shaft diameter and the thickness, when a flat key is preferred to the square form, is usually about one-sixth of the shaft diameter; these proportions are varied somewhat by different manufacturers. The taper of American Standard square and flat keys is 1/8 inch per foot.

Keyseating Machines. The machines which are designed especially for cutting keyseats or keyways in the hubs of pulleys, gears, etc., are generally known as *keyseaters*. Machines of this class usually have a base or frame which contains mechanism for imparting a reciprocating motion to a cutter bar, which moves vertically for cutting a keyseat in the work. There are several types of machines which are used for internal keyseating operations in addition to the machines designed especially for this work. Broaching machines as well as slotters are commonly used, and keyseating is also done to some extent in shapers and planers.

Kilogram-Calorie. A kilogram-calorie, frequently simply termed "calorie," is a thermal unit based on the metric system, designating the amount of heat required for raising the temperature of one kilogram of pure water one degree C. One kilogram-calorie = 3.968 British thermal units = 1000 gram calories.

Kilogram-Meter. This is a unit of work in the metric system, designating the work done in raising one kilogram to a height of one meter. One kilogram-meter = 7.233 foot-pounds.

Kilogram Per Square Centimeter. This is a unit in the metric system for measuring pressure. One kilogram per square centimeter = 14.223 pounds per square inch.

Kilogram Per Square Millimeter. This is a unit in the metric system for measuring pressure. One kilogram per square millimeter = 1422.32 pounds per square inch.

Kilovolt-Ampere. The term *kilovolt-ampere* (kva.), equal to 1000 volt-amperes, is used to express the *apparent power* in a reactive circuit, i.e., the product of the effective values of the current and the voltage, IE, in a reactive circuit. The term "kilowatt" (kw.), equal to 1000 watts, on the other hand, expresses the *true power*, IE $\times$ cos θ in a reactive circuit, and is the reading obtained by a wattmeter applied to the circuit. The ratio of the watts to the volt-amperes is called the *power factor*. For example, assume an alternating-current generator supplying a load of 800 kilowatts, the power factor of which is 80 per cent. The true rating of such a generator, or the one on which the capacity of the prime mover should be based, would be 800 kilo-

watts, while the apparent rating of the generator would be $\frac{800}{0.80}$ $=$ 1000 kilovolt-amperes. To avoid any misunderstanding, the rating usually appears as follows: 1000 kva. (800 kw., 0.8 power factor). For direct-current generators, however, the rating is always given in kilowatts, because these machines always operate on non-inductive load, the true power is equal to IE and no power factor is involved. The rating of a synchronous machine is usually determined by its permissible temperature rise caused by the currents in the armature and the field windings. This rise increases with increasing load and with decreasing power factor. Thus for a given kilovolt-ampere output, the total heat losses are larger for low than for high power factors, the difference being due to the heat generated by the increased field current which is required to overcome the armature reaction and maintain the given current and terminal voltage.

Kilowatt. The unit of power generally adopted for all electrical work and also frequently used in mechanical engineering is known as the "kilowatt." One kilowatt equals 1.34 horsepower, or one horsepower equals 0.746 kilowatt. The latter figure is the exact standard relationship between the kilowatt and the horsepower used by the United States Bureau of Standards, and may, therefore, be assumed as the exact equivalent of horsepower in electrical units. An effort has been made in scientific and engineering circles to substitute the kilowatt for the indefinite horsepower as the unit measurement of power. The kilowatt is just as good a mechanical unit as an electrical one, and it has the advantage of being a logical rating expressing a definite relation to the absolute system of measurements in general use for scientific purposes. One of the advantages of the kilowatt is that it is an absolute international unit which is not true of the horsepower. The latter, in countries using the metric system, is calculated as the equivalent of 75 kilogram-meters per second, which equals 542.5 foot-pounds per second, or 32,550 foot-pounds per minute—an appreciable amount less than the 33,000 foot-pounds constituting the British and American horsepower. The adoption of the kilowatt as a unit of power would avoid having generators rated in kilowatts while their driving machinery and electric motors are rated in horsepower.

Kilowatt-Hour. A unit of work or energy equivalent to one kilowatt acting one hour. 1 kilowatt hour $=$ 1000 watt-hours $=$ 1.34 horsepower-hour $=$ 2,655,200 foot-pounds $=$ 3,600,000 joules $=$ 3415 B.T.U. $=$ 3.54 pounds of water evaporated at 212° F. $=$ 22.8 pounds of water raised from 62° to 212° F.

Kinetic Energy. Energy, in mechanics, is defined as the capacity of a body for performing work and is measured in foot-

pounds. It may be either *potential,* as in the case of a body of water stored in a reservoir, which is capable of doing work by means of a water turbine if released, or *kinetic,* which is the energy of a moving body. The kinetic energy of a moving body is the work which the body is capable of performing against a resistance before it is brought to rest. The kinetic energy of any moving body is equal to the work which has brought it from its state of rest to its actual velocity. The measure of the kinetic energy is the product of the weight of the body multiplied by the height from which it must fall to acquire its actual velocity; hence, if $V =$ velocity in feet per second; $W =$ weight of the body; $g =$ acceleration due to gravity $= 32.2$; then, the kinetic energy E, in foot-pounds, equals:

$$E = \frac{WV^2}{2g}.$$

In a rotating body, the kinetic energy may be found by the same formula, if V is the velocity of the center of gyration.

Kinite. Kinite is the trade name for an alloy steel containing chromium and cobalt, but no tungsten, and has been found especially adapted for making dies requiring great resistance to abrasion or wear. Trimming dies for hot forgings, for example, are among the tools for which the material is well suited. Furthermore, the material is practically non-corrosive, and has been found excellent for the making of glass and other molds requiring a high heat-resisting material.

Kirchhoff's Laws. Kirchhoff's first law is as follows: In any closed circuit, the algebraic sum of the electromotive forces, in volts, will be equal to the algebraic sums of the currents in the conductors multiplied respectively by the resistances of the conductors through which they flow. In other words, all the electric forces in the circuit are balanced. Kirchhoff's second law is as follows: If any number of wires converge at a point, the sum of the currents flowing toward the point will be just equal to the sum of the currents flowing away from the point; or, in other words, the currents must balance.

Kish. The name "kish" is sometimes given in metallurgy to the carbon or graphite which appears on the surface of the iron in a blast furnace during the process of tapping. It is also used to designate the carbon which segregates in the form of plates in cast iron during the solidification.

Knife-Edge Bearings. So-called "knife-edge" bearings are used on weighing and testing machines. When the knife-edge bearing as well as the seat are made of the proper material, the knife-edge will sustain loads up to 10,000 pounds per inch of length; but ordinarily about 5000 pounds is the usual limit of

pressure. The knife-edge, as well as the seat bearing upon it, should be made from tool steel having a carbon content of from 0.9 to 1 per cent. The knife-edge should be properly supported underneath its whole length in order to prevent deflection. The angle of the knife-edge should be 90 degrees for heavy loads. It should have a very slight flat at the extreme point, so small, however, that it is barely visible, because a pronounced flat or radius at the edge decreases the accuracy of the device. This flat may be obtained by rubbing with an oilstone. The seat against which the knife-edge bears, if made of an angular form, should be provided with a small round at the vertex of the angle.

Knife File. Files of this class derive their name from the fact that they resemble somewhat the blade of a knife. The section is tapering toward one edge and in a lengthwise direction toward the point. The teeth are double-cut, mostly bastard; this type is used for many purposes to which the knife shape is adapted.

Knuckle-Joint Embossing Press. Knuckle-joint power presses are used extensively for embossing coins, medallions, and other intricate forms, as well as for lettering or embossing that requires a large amount of pressure for a comparatively short time. Because of their use for this class of work these presses are often termed "coining" presses. In the knuckle-joint embossing press, the slide is operated by two knuckle arms. As the knuckle arms are straightened, the vertical movement of the slide is small, compared with the horizontal movement of the knuckle. It is this slow increasing pressure that distinguishes the knuckle-joint press from other types. Such a pressure enables the metal to flow under the force of the punch, and fine intricate embossing is possible.

Knurling. The forming of a series of fine ridges upon the periphery of a circular part, such as a screw-head, handle, or knob, is known as *knurling* or *nurling*. The purpose of this checked or milled surface is usually to increase the grip of the hand and thus facilitate rotating the knurled part, although knurling is also done in many cases merely to produce an ornamental effect. The handles of gages and other tools are often knurled, and the round thumb-screws used on instruments, etc., usually have knurled edges. A knurling tool has a hardened disk or a set of disks mounted in a holder; when knurling, one or two of these disks (the number depending upon the type of knurling tool used) are pressed against the unhardened work, and rotate with it, thus reproducing upon the work the knurling which has been formed upon the periphery of the knurl itself. A common type of knurling tool is equipped with two knurls having teeth or ridges which incline to the right on one knurl and to the left

on the opposite knurl. When these two knurls are pressed against the work as the latter revolves, one knurl forms a series of left-hand ridges and the other knurl right-hand ridges, which cross and form a diamond-shaped knurling. Knurling is done in the lathe either by a hand-controlled tool or by a tool which is held in the toolpost the same as for turning.

Ko. This is a Chinese capacity measure, legalized in 1908, equal to 0.1035 liter, or 0.1094 quart.

Koroseal. Does not swell when exposed to many oils and greases nor disintegrate in the presence of corrosive chemicals; will resist the action of chromic acid and hot concentrated nitric acid; can be molded to any shape. Produced in a variety of colors; odorless. High cost precludes its adoption as a general substitute for rubber, but appears to be superior to rubber for certain applications. Valuable for piston packing, because of the oil-tight seal provided.

Koroseal-Coated Paper. A paper coated with a thin layer of Koroseal, a rubber-like substance impervious to deteriorating fluids and gases. The coated paper is resistant to acid, oil, water, air, and light. Offers protection for exposed surfaces of machinery while in ocean transit, since coverings can be made from it which will exclude the salt sea air.

Kovar. An alloy having a thermal expansion that permits permanent sealing of the metal to glass. It is unaffected by mercury and mercury vapors. Used in the electrical industry for sealing of metal to glass, as in electronic tubes, etc.

Kux Hi-Heat. Non-oxidizing alloy, highly resistant to corrosion; dense, hard, and tough, taking a high permanent polish. Tensile strength, from 45,000 to 50,000 pounds per square inch; hardness, from 250 to 270 Brinell. Suitable for use where resistance to heat and corrosion is required, as in creamery, dairy, and food-product equipment; also used for die-casting dies and synthetic plastic molds.

Kwan. Kwan is the Japanese unit of weight, equal to 3.75 kilograms or 8.2673 pounds avoirdupois. One kwan is divided into 1000 mommes.

Kyanizing. Kyanizing is a treatment applied to wood to render it proof against decay, by saturating it with a solution of corrosive sublimate (mercuric chloride, $HgCl_2$). The saturating is done either in open tanks or under pressure in closed tanks. Wood which is kyanized is used to a great extent by textile plants in structures that are subjected to acid fumes and conditions that produce rapid decay.